GEOLOGICAL SURVEY BRANCH
DEPARTMENT OF MINES AND ENERGY
GOVERNMENT OF NEWFOUNDLAND AND LABRADOR

EARLY ORDOVICIAN TRILOBITE FAUNAS OF THE BOAT HARBOUR AND CATOCHE FORMATIONS (ST. GEORGE GROUP) IN THE BOAT HARBOUR–CAPE NORMAN AREA, GREAT NORTHERN PENINSULA, WESTERN NEWFOUNDLAND

William Douglas Boyce

Report 89-2

St. John's, Newfoundland
1989

COVER

Dorsal view of *Randaynia saundersi* gen. et sp. nov., collected from the Lower member of the Boat Harbour Formation (St. George Group) on Old Ferrolle Island, Brig Bay area.

'Remember that trilobites, with few exceptions—mainly Cullison's work, are poorly known in the Canadian of the Ozarks, Mississippi Valley and Appalachians'
(Dr. R.H. Flower, personal communication, 1978).

This study is partly based on a Master's thesis initially undertaken at Memorial University of Newfoundland, and is dedicated to C.H. Kindle, pioneering western Newfoundland paleontoiogist.

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90-04119/

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Telephone: (709) 576-3159
Telex: 016-4724
Fax: (709) 576-3493

This project is a contribution to the Canada–Newfoundland Mineral Development Subsidiary Agreements 1976-1989: project carried out by Newfoundland Department of Mines and Energy.

ISBN 0-920769-46-2

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ABSTRACT

Detailed biostratigraphic sampling of the Lower Ordovician Boat Harbour and Catoche formations, in the Boat Harbour–Cape Norman area of western Newfoundland, have yielded hitherto unrecorded trilobite faunas, so far unparalleled in richness and diversity anywhere in the Appalachians.

Thirty-seven species are systematically treated. One new genus is proposed (Randaynia). *Two new genera are recognized but left in open nomenclature because of inadequate material (Gen. nov. A, Gen. nov. B). Included among the forms are fourteen new species,* Leiostegium proprium, Hillyardina minuspustulata, H. levis, Parahystricurus smithiae, Bolbocephalus stevensi, B. kindlei, Jeffersonia angustimarginata, Peltabellia knighti, Strigigenalis brevicaudata, Benthamaspis hintzei, Grinnellapis newfoundlandensis, Ischyrotoma parallela, Randaynia saundersi *and* R. langdoni. *Six new species are recognized but because of inadequate material are not named* (Illaenus *sp. nov., Gen. nov. A sp. nov. A, Gen. nov. B sp. nov. A,* Petigurus *sp. nov. A.*, Benthamaspis *sp. cf.* B. conica *and* Uromystrum *sp. cf.* U. affine). Hyperbolochilus *Ross, 1951 and* Tanybregma *Jell and Stait, 1985 are junior synonyms of* Hillyardina *Ross, 1951.* Vermilionites *Kobayashi, 1955 is a junior synonym of* Hystricurus *Raymond, 1913.* Benthamaspis *Poulsen, 1946 is assigned to the bathyurid subfamily Bathyurellinae Hupé, 1953.*

Three trilobite-based biostratigraphic range zones are proposed. In ascending order, these are as follows:

1) Randaynia saundersi *Zone*
2) Strigigenalis brevicaudata *Zone, and*
3) Strigigenalis caudata *Zone*

The new trilobite zones are correlated with both the Ibexian trilobite zonation of Utah–Nevada and the stages of the Canadian Series.

INTRODUCTION

For over a century, there has been a distinct paucity of systematic paleontological research into the trilobite faunas of the autochthonous Early Ordovician St. George Group, of western Newfoundland. Indeed, until recently the most comprehensive treatment was that of Billings (1865). This was because the lithostratigraphy of the Cambrian–Ordovician carbonates, as a whole, was poorly understood, and most previous work was confined to large-scale, regional geological mapping.

Before the studies of Stevens (1970), Knight (1977a,b, 1978, 1980a,b, 1983), Levesque (1977), Knight and Saltman (1980), Klappa *et al.* (1980), Stouge and Godfrey (1982), Pratt and James (1982) and Knight and James (1987, 1988), the lithostratigraphy of the St. George and Table Head groups was poorly understood. With the exception of Schuchert and Dunbar (1934), Kindle (1945) and Johnson (1949), most previous workers assumed, 1) the St. George Group consisted of sparsely fossiliferous dolostone, and 2) only the autochthonous Table Head Group and the allochthonous Cow Head Group contained any appreciable amount of fossiliferous Ordovician limestone (e.g., Oxley, 1953; Nelson, 1955; Woodard, 1957). Consequently, with the exception of Billings (1865), Raymond (1913, 1925), Kindle (1945), Johnson (1949) and Whittington (1953), most previous paleontological investigations have concentrated on the Table Head Group (Whittington, 1961, 1965, 1968; Whittington and Kindle, 1963, 1969) and the Cow Head Group (Rasetti, 1954; Kindle and Whittington, 1958; Whittington, 1961, 1963, 1968; Whittington and Kindle, 1963, 1969). Of the studies, including trilobites from the St. George Group, only Billings (1865), Raymond (1913, 1925) and Whittington (1953) provided detailed systematic descriptions.

Most of the original studies in western Newfoundland were regional mapping efforts in relatively inaccessible terrains (e.g., Cooper, 1937; Betz, 1939; Walthier, 1949; Oxley, 1953; Nelson, 1955; Woodard, 1957; Baird, 1960; Lilly, 1961, 1963), some of which were summarized and augmented by Cumming (1983). The priorities of producing geological maps and describing such areas, resulted in the collection of only the most common or striking fossils (generally gastropods and cephalopods) from outcrop.

Biostratigraphic correlations with the standard Ross (1951)–Hintze (1953) Ordovician trilobite zones of Utah–Nevada have been hampered because of the insufficient systematic investigation of the St. George trilobite faunas. Most previous correlations have been based on the generic similarity of the trilobite faunas (e.g., Kindle and Whittington, 1958; Whittington, 1968; Whittington and Kindle, 1963, 1969). Ross and Ingham (1970) and Fahraeus (1977a) have demonstrated the inherent inaccuracy of this practice. Their documented examples show that faunas of high generic similarity may be of radically different ages. However, Fortey (1974, 1976, 1979a, 1980b, 1983, 1986), Fortey and Skevington (1980), and Fortey *et al.* (1982) have proposed regional and intercontinental correlations based on common trilobite species. These correlations have been confirmed by graptolite and conodont data in the same studies. Correlations based on specific identity (i.e., the presence of one or more common species) are considered to be more reliable than those based on generic similarity.

Biostratigraphic correlations of the St. George trilobite faunas with those of the classic deposits of the Canadian Series in New York– Vermont and Missouri–northern Arkansas (Fahraeus, 1977b; Flower, 1964; Whittington, 1968) have also been hampered. This is a result of the lack of detailed lithostratigraphic and systematic studies of the faunas of these areas. The most complete systematic studies of the Early Ordovician trilobite faunas of New York– Vermont are those of Cleland (1900, 1903), Dwight (1884), Fisher (1954), Flower (1968b,c), Taylor and Halley (1974), Welby (1962), Whitfield (1886, 1889a,b, 1890, 1897) and Whittington (1953), and for Missouri–Northern Arkansas, those of Cullison (1944), Heller (1954) and Ulrich *et al.* (1931). Trilobite-based correlations between the classic Canadian Series deposits and the Ross–Hintze zones have so far proven difficult because these studies are generally out-of-date. Macrofaunal correlations have largely been based on the generic similarities of the cephalopod and gastropod faunas (Flower, 1964, 1968a,b,c, 1976, 1978).

This report is presented as two separate but complementary studies; these are:

1) Descriptive Systematic Paleontology

The objective of this section of the study, is a systematic taxonomic analysis of the trilobite faunas of the Boat Harbour and Catoche formations in the Boat Harbour–Cape Norman region.

2) Biostratigraphy

The biostratigraphic aspects of this study have the most practical value, the main objectives of which are:

i) to erect a biostratigraphic zonation for the Boat Harbour and Catoche formations,

ii) to correlate the trilobite faunas with those of the standard Ross (1951)–Hintze (1953) Ordovician trilobite zones of Utah–Nevada, and the classic deposits of the Canadian Series in New York–Vermont and Missouri–northern Arkansas (Fahraeus, 1977b; Flower, 1964; Whittington, 1968), and

iii) to propose, on the basis of the above correlations, a correlation of the Canadian Stages proposed by Flower (1964, pages 17 to 19) with the Ross–Hintze zones.

All biostratigraphic correlations proposed in this study are based on specific identity (i.e., the presence of one or more common species).

PREVIOUS WORK

For many years the most complete work on the trilobite faunas of the St. George Group was that of Billings (1865), although Raymond (1913, 1925) and Whittington (1953) revised some of Billings' taxa. Kindle (1945) and Johnson (1949), in unpublished manuscripts, and Whittington and Kindle (1969), added preliminary identifications of several genera and species not known to Billings. However, it was not until the studies of Boyce (1978, 1979a,b, 1983b), Fortey (1979a) and Boyce *in* Stouge and Boyce (1983) that major additions were made to Billings' pioneering work.

Fortey (1979a) reinvestigated, in detail, the original collection area of Billings' described trilobites on the Port au Choix Peninsula (Figure 1). Here, Fortey (1979a) recognized two successive faunas, comprising more than twice the number of trilobite species than Billings had recorded. Boyce (1978, 1979a,b, 1983b) discovered two previously unknown faunas in the Boat Harbour–Cape Norman region (Figure 1), stratigraphically beneath those found by Fortey (1979a). These new faunas were found to be separated by a significant faunal and sedimentological break. Both Fortey (1979a) and Boyce (1979a,b, 1983b), correlated their faunas with those of the standard Ross (1951)–Hintze (1953) zonation of Utah–Nevada. For the first time, these correlations were based on common species rather than genera.

SAMPLING LOCALITIES

Preliminary trilobite collections were obtained from the study area, during the summer of 1976. After it became evident that previously unknown faunas were represented, further collections were obtained in the following year. Simultaneously, a detailed bed-by-bed composite lithostratigraphic section was measured at Boat Harbour (Figure 1). Individual beds were measured to the nearest centimetre. Small covered intervals (less than 1 m) were also measured but larger ones were estimated using paced distances and bed geometry. Several covered intervals in the Boat Harbour sections were not measured by the author. Instead, thickness values obtained by Knight (1977b) and Pratt (1979) have been utilized. These intervals are indicated in the lithostratigraphic sections of Appendix 1.

During the summers of 1978, 1985 and 1987, the Boat Harbour section was revisited and certain problematical intervals were re-examined and sampled, bed-by-bed, for trilobites. Other macrofossils were also collected (i.e., articulate and inarticulate brachiopods, cephalopods, echinoderms (eocrinoid debris), gastropods and ostracodes). Each fossiliferous horizon was sampled, even if trilobites were not present, and additional samples were taken for conodont analysis. Ongoing collaboration is underway with Drs. I. Knight (Newfoundland Department of Mines and Energy) and S. Stouge (Geological Survey of Denmark) on the new trilobite and conodont faunas recovered. Preliminary results of this collaboration have already been published (Stouge, 1982; Stouge and Boyce, 1983; Boyce *et al.*, 1983; Knight and Boyce, 1984; Boyce, 1985, 1986; Stouge, 1986).

During the summer of 1978, a reconnaissance lithostratigraphic section was measured north of the lighthouse at Cape Norman, 7 km northeast of Boat Harbour (Figure 1). Also, each fossiliferous horizon was sampled for trilobites and conodonts. In 1985, a further detailed surveying and sampling program was completed (Boyce, 1986).

During the field seasons of 1976 to 1978 and 1980 to 1987, additional trilobite (and conodont) collections were made in the following areas: Canada Bay, Hare Bay, Burnt Island, Schooner Island, Brig Bay, St. John Bay, Eddies Cove West, Port au Choix–Back Arm, Port Saunders–Keppel Island, Hawkes Bay–River of Ponds Lake, Bateau Barrens Road, Parson's Pond, Bonne Bay Little Pond and the Port au Port Peninsula (Figure 1).

LITHOSTRATIGRAPHY

TERMINOLOGY

Autochthonous, Lower Ordovician carbonates in western Newfoundland constitute the St. George Group (Kluyver, 1975; Knight, 1978, 1980b; Knight and James, 1987, 1988). Knight (1978, 1980b) subdivided these platformal limestones in the Boat Harbour–Cape Norman area into three lithostratigraphic units–the Watts Bight, Boat Harbour and Catoche formations. Knight's terminology has been widely utilized (Barnes, 1984; Boyce, 1978, 1979a,b, 1981b, 1983a,b, 1985, 1986; Haywick and James, 1984; James and Stevens, 1986; Klappa *et al.*, 1980; Knight, 1980a, 1983, 1984, 1985, 1986; Knight and Boyce, 1984; Knight and Edwards, 1978a,b; Knight and James, 1987, 1988; Knight and Saltman, 1980; Lane, 1984; Saunders and Strong, 1986; Snow and Knight, 1979; Stouge, 1980, 1981, 1982, 1983a,b, 1984, 1986; Stouge and Boyce, 1983; Stouge and Godfrey, 1982 and Williams *et al.*, 1987), and has been adopted here. The component formations of the St. George Group in the study area (Figure 2), are described below. The descriptive carbonate terminology follows Dunham (1962).

WATTS BIGHT FORMATION

The Watts Bight Formation (Knight, 1978) is the lowest unit of the St. George Group and consists of 80 to 100 m of dark grey to black, vuggy, bituminous and sucrosic diagenetic dolostones. The dolostones, which are massive and

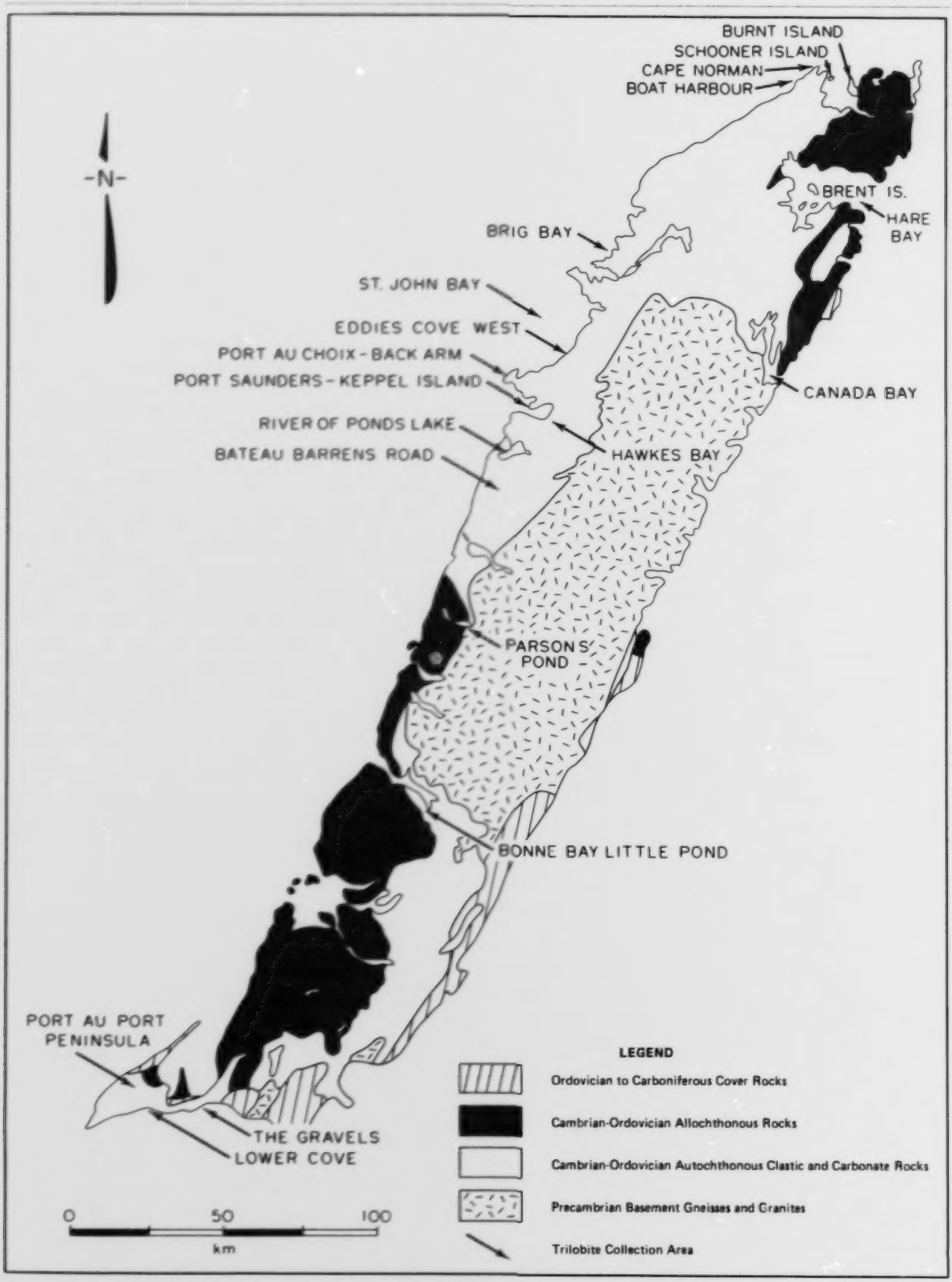

Figure 1. *Geological elements and trilobite collection areas of western Newfoundland.*

<table>
<tr><th>SYSTEM</th><th>SERIES</th><th>GROUP</th><th>KNIGHT (1977A,B)</th><th>KNIGHT (1978)</th><th>KNIGHT (1980B)
STOUGE (1981)
BOYCE (1983B)</th><th>THIS STUDY</th></tr>
<tr><td rowspan="6">ORDOVICIAN</td><td rowspan="2">ARENIG</td><td rowspan="6">ST GEORGE GROUP</td><td colspan="2">DIAGENETIC CARBONATES</td><td colspan="2">DIAGENETIC CARBONATES</td><td>CATOCHE FORMATION</td><td>DIAGENETIC CARBONATES</td><td>CATOCHE FORMATION</td><td>DIAGENETIC CARBONATES</td></tr>
<tr><td colspan="2" rowspan="2">CATOCHE FORMATION</td><td colspan="2">CATOCHE FORMATION</td><td>LOWER LIMESTONE SEQUENCE</td><td>LOWER LIMESTONE SEQUENCE</td></tr>
<tr><td rowspan="4">TREMADOC</td><td rowspan="3">UNNAMED UNIT</td><td>UPPER
— PEBBLE BED —
MEMBER</td><td rowspan="3">BOAT HARBOUR FORMATION</td><td>UPPER
— PEBBLE BED —
MEMBER</td><td rowspan="3">BOAT HARBOUR FORMATION</td><td>BARBACE COVE MBR.
— PEBBLE BED —</td></tr>
<tr><td rowspan="2">WATTS BIGHT FORMATION</td><td>UPPER DOLOSTONE – LIMESTONE FACIES</td><td>LOWER MEMBER</td><td>LOWER MEMBER</td><td>LOWER MEMBER</td></tr>
<tr><td colspan="2">WATTS BIGHT FORMATION</td><td colspan="2">WATTS BIGHT FORMATION</td><td colspan="2">WATTS BIGHT FORMATION</td></tr>
</table>

Figure 2. *Review of the St. George Group lithostratigraphic nomenclature in the Boat Harbour–Cape Norman study area.*

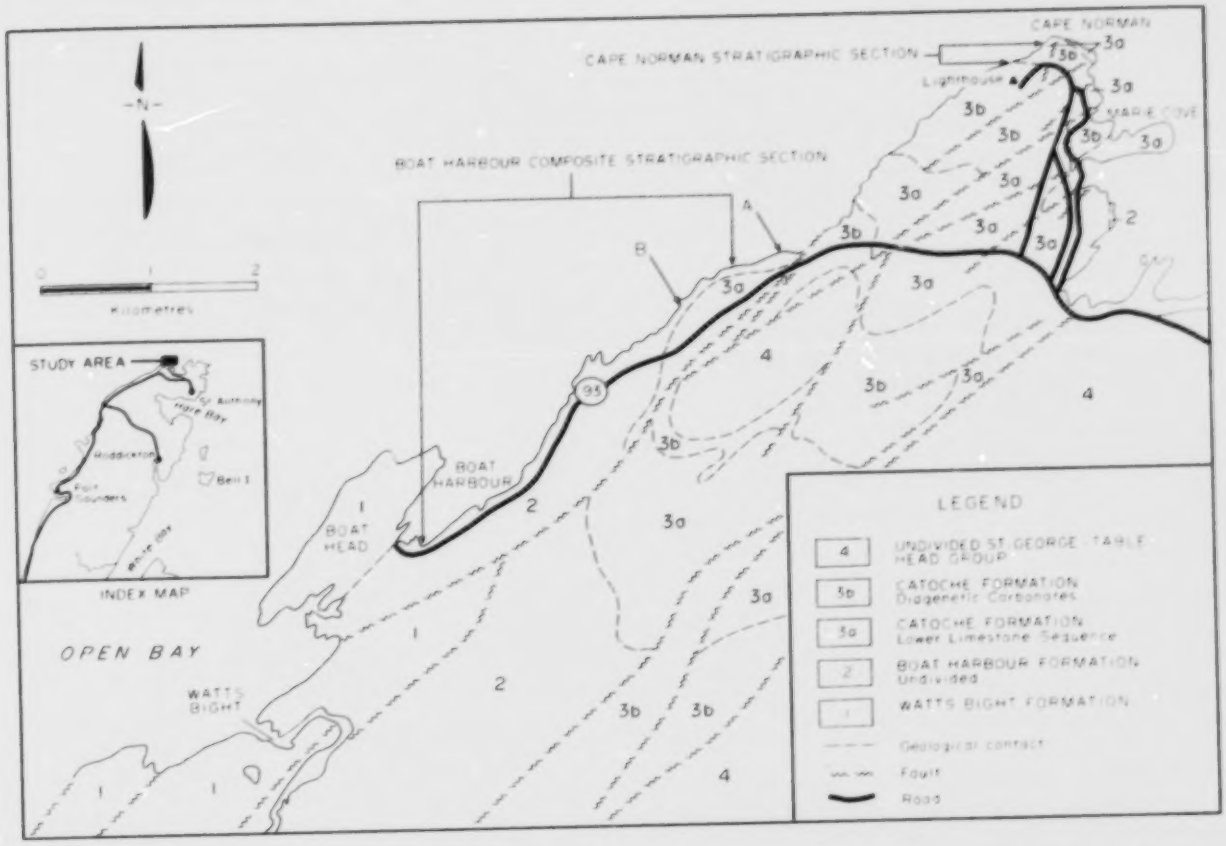

Figure 3. *Geology of the Boat Harbour–Cape Norman study area and location of measured stratigraphic sections. Geology modified from Knight and Edwards (1978a,b). A and B indicate sampled conodont localities of Barnes and Tuke (1970).*

thick bedded, have a cream, light grey and white burrow-mottling and are fine to coarsely crystalline. The dolostones replace bioturbated lime mudstones and stromatolitic boundstones, consisting of mounds up to 2 m in diameter. The formation, especially the lower part, is rich in black and grey chert that occur as nodules and streaks, and which also replaces stromatolites. The middle of the formation consists of thin bedded, bioturbated, grey and honey-coloured lime mudstones and wackestones, dolostones, packstones and grainstones, some yellow dolostones and coarse crystalline, honey-coloured dolostones (Knight, 1977a,b, 1978, 1980a).

The unit is best exposed at the type section that commences on the coast south of Watts Bight, 2 km southwest of Boat Harbour and concludes on the northern shoreline of Boat Head (Figure 3).

The Watts Bight Formation is sparsely fossiliferous and, to date, has only yielded silicified ellesmeroceratid cephalopods and large, low-spired gastropods.

BOAT HARBOUR FORMATION

The Boat Harbour Formation (Knight, 1980b; Stouge, 1981) is about 132-m thick and is divided into two members (Knight, 1978, 1980b, 1986; Knight and James, 1987, 1988); the Lower member and the Barbace Cove Member, respectively (Figure 2).

In the study area, the Boat Harbour Formation may disconformably overlie the Watts Bight Formation. Knight (1980a, page 5) reports a breccia zone on the northeastern point of Boat Head above the uppermost Watts Bight dolostones (Figure 3). A dolomite–chert breccia horizon, cemented by chert and fine crystalline dolostone, also occurs at the contact between the two formations, south of the study area in the Eddies Cove East–Salmon River area (Knight, 1980a). There the breccia vertically penetrates the top beds of the Watts Bight Formation. These features suggest that either a disconformity (of unknown magnitude) or a stratabound collapse breccia (possibly related to solution of

evaporites) occurs at the Watts Bight–Boat Harbour contact (Knight, 1980a, page 5, 1985).

Lower member

The basal 45 m of the Lower member of the Boat Harbour Formation is poorly exposed in the type section at Boat Harbour, where it underlies the bay (Figure 3). However, inland exposures of this interval occur south of Boat Harbour (Knight, 1978).

Knight (1977a,b) originally included the basal 45 m of the Lower member of the Boat Harbour Formation in the upper part of the underlying Watts Bight Formation, calling it the Upper Dolostone–Limestone facies. He subsequently reassigned it to the 'Unnamed Unit', as the Boat Harbour Formation was originally called (Knight, 1978, page 141).

The Lower member of the Boat Harbour Formation is about 116-m thick. The basal 45 m consists of 1) thin bedded and laminated microcrystalline dolostones, 2) vuggy, medium crystalline honey-coloured diagenetic dolostones, 3) grey and honey-coloured limestones, 4) diagenetic pseudobreccias* replacing burrowed lime mudstone and wackestone, and 5) rare beds of dull brown and white burrow-mottled, blocky weathering, vuggy, coarse crystalline, dark grey to black diagenetic dolostone (Knight, 1978).

To date, fossils have not been recovered from the basal 45 m of the Lower member of the Boat Harbour Formation in the study area.

The upper 71 m of the Lower member of the Boat Harbour Formation is best exposed in the type section along the coast, northeast of Boat Harbour (Figure 3). It consists of repetitive shoaling-upward sequences. Four lithofacies are commonly developed in these sequences. From bottom to top they are: 1) stromatolitic and thrombolitic lime boundstones, 2) extensively bioturbated lime mudstones and wackestones, 3) sparsely bioturbated dolomitic lime mudstones and wackestones, and 4) laminated primary dolostones (dolomite mudstones and wackestones) and dolomitic lime mudstones.

The stromatolitic and thrombolitic lime boundstones are light blue-grey and hackly weathering, massive and irregular bedded, sparsely fossiliferous and dark blue-grey, when fresh. The boundstones occur as isolated mounds and coalesced mound complexes and commonly contain black, orange or white chert. Lime grainstones and packstones, which are locally richly fossiliferous and oölitic, are commonly associated with the boundstones and generally occur in the intermound areas.

The extensively bioturbated lime mudstones and wackestones are light blue-grey, grey and rubbly weathering, massive and planar bedded, and dark blue-grey and grey when fresh. The abundant horizontal and vertical burrows, trails, etc., are preserved by buff and yellow weathering argillaceous dolomitic material. These rocks are sparsely fossiliferous and generally only yield planispiral gastropods and rare cephalopods.

The sparsely bioturbated, dolomitic lime mudstones and wackestones are light blue-grey and blocky weathering, massive to thin, planar bedded and laminated, and dark blue-grey, when fresh. The rare horizontal burrows and trails are preserved by buff and yellow weathering argillaceous dolomitic material. Thin, irregular dolomitic laminae and layers, ripple-marks, flat-pebble conglomerates, and small scours and channels also occur. These rocks are moderately fossiliferous.

The laminated primary dolostones (dolomite mudstones and wackestones) and dolomitic lime mudstones complete many of the shoaling-upward sequences. These rocks are buff- and cream-weathering, thin- and planar-bedded, and dark blue-grey and grey when fresh and may display mudcracks. They are apparently unfossiliferous.

A distinctive 'pebble bed' (Plates 1A and 1B) occurs at the top of the Lower member of the Boat Harbour Formation (Knight, 1977b, 1978, 1980b; Boyce, 1978, 1979a,b; Stouge, 1980, 1981, 1982; Stouge and Boyce, 1983) (Bed 9 of Section BHS-6, Appendix 1). This 6-cm-thick bed consists of buff-weathering, fine-grained, apparently unfossiliferous light grey dolostone that contains the following pebble types: 1) subangular to well rounded, white vug-quartz clasts up to 3 cm in diameter, 2) angular, grey to black chert clasts up to 6-cm long, 3) subangular to subrounded, grey chert clasts containing tiny pyrite crystals and 4) pyrite nodule clasts up to 1 cm in diameter. Small, straight, symmetrical bimodal ripples occur in the bed but, as Knight (1978, page 143) reports, 'the clasts show no evidence of sorting or movement by currents and 'pebble' density is variable within the horizon.' Three, 9- to 43-cm-thick beds of fine crystalline diagenetic dolostone occur immediately beneath the 'pebble bed' (Beds 6 to 8 of Section BHS-6, Appendix 1). These beds, which total 91 cm in thickness, are planar bedded, bioturbated and rippled, apparently unfossiliferous and light blue-grey, when fresh. They represent dolomitized limestones (Knight, 1978). The top of the 'pebble bed' (Plate 1B) is irregular, pitted and pot-holed (Knight, 1978) and capped by a thin, 1-cm seam of apparently unfossiliferous dark grey argillaceous dolomite wackestone (Bed 10 of Section BHS-6, Appendix 1). This thin seam forms the top of the Lower member of the Boat Harbour Formation.

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* Pseudobreccia–a name coined by Cumming (1968) for limestone–primary dolostone that has been intensely, diagenetically dolomitized so that the original rock remains only as clots, streaks and small masses surrounded by prismatic crystals and mosaics of white sparry dolomite (Knight, 1977b, page 21).

Plate 1. *(1a) The 'pebble bed' of Knight (1977b, 1978) as exposed at Boat Harbour. (Bed 9 of Section BHS-6, Appendix 1). Metre stick for scale; (1b) Closeup of 'pebble bed' showing irregular surface capped by thin seam of argillaceous dolomite wackestone (Bed 10 of Section BHS-6). Metre stick for scale. (Both photos courtesy of Dr. I. Knight).*

The upper 71 m of the Lower member of the Boat Harbour Formation is, locally, abundantly fossiliferous. To date, it has yielded articulate and inarticulate brachiopods, straight and curved cephalopods, echinoderms (eocrinoid fragments), high- and low-spired and planispiral gastropods, as well as trilobites and conodonts.

Barbace Cove Member

The Barbace Cove Member of the Boat Harbour Formation (Knight and James, 1987, 1988) consists of interbedded limestones and dolostones. It is 16-m thick, and is best exposed in the type section along the coast northeast of Boat Harbour (Figure 3). Here, the base of the member is placed at the bottom of a 29-cm bed of buff-weathering, massive, fine crystalline, apparently unfossiliferous light blue-grey diagenetic dolostone, containing rare 5 mm diameter black chert clasts (Bed 11 of Section BHS-6, Appendix 1). The top of the member (and the formation) is defined by the base of the Catoche Formation, which overlies a 2.42-m bed of laminated and mud-cracked, apparently unfossiliferous blue-grey lime mudstone and wackestone having buff dolomitic laminae (Bed 40 of Section BHS-6, Appendix 1).

The Barbace Cove Member includes 1- to 7-m-thick sequences of variably interbedded rock types. These include thin, irregularly bedded, extensively bioturbated, fossiliferous light blue-grey lime mudstones and wackestones to skeletal packstones having dolomitic burrow mottling; small circular boundstone mounds up to 25 cm in diameter; and 3-cm-thick beds and lenses of locally cross-laminated, intraclastic and skeletal packstone and grainstone. Upwards, the limestones in the sequences become unfossiliferous. Finely laminated and mudcracked primary dolostones (dolomite mudstones and wackestones) and dolomitic lime mudstones cap the sequences. Locally, these rocks contain small, exceptionally well preserved stromatolites and lenses of intraclastic dolomite packstone and grainstone, having flat intraclasts up to 10 cm in length. One bed of lime boundstone, which consists of steep-sided circular to elliptical mounds up to 1 m in diameter, occurs near the base of this succession (Bed 25 of Section BHS-6, Appendix 1).

The Barbace Cove Member is abundantly fossiliferous. To date, it has yielded articulate brachiopods, straight and curved cephalopods, high- and low-spired and planispiral gastropods, as well as trilobites and conodonts.

CATOCHE FORMATION

The Catoche Formation was originally defined by Kluyver (1975) at Catoche Point on the Port au Choix Peninsula, south of the study area (Figure 1). Knight (1977a,b, 1978, 1983) subsequently restudied and redefined it at the type locality, and measured it in the study area as well. Here, the formation consists of a lower limestone sequence at least 40-m thick and an upper 25- to 50-m-thick sequence of diagenetic dolostones, known informally as the 'Diagenetic Carbonates' (Knight, 1977a,b, 1978).

The lower limestone sequence consists predominantly of lime mudstones and wackestones. These rocks are characteristically light blue-grey and rubbly weathering, thin and lenticular bedded to massive and planar bedded, moderately bioturbated, fossiliferous, and dark blue-grey and grey when fresh. Burrows and trails are preserved by buff-weathering, argillaceous dolomitic material. Lenses of skeletal and intraclastic lime packstone and grainstone and minor beds of grey weathering, apparently unfossiliferous diagenetic dolostone, also occur.

The basal beds of the lower limestone sequence are exposed at the top of the measured Boat Harbour sequence, conformably overlying the uppermost beds of the Boat Harbour Formation (see Appendix 1). The uppermost beds of the lower limestone sequence are exposed in the seacliffs at Cape Norman (Figure 3). There, spectacular patches of white weathering dolomite–pseudobreccia occur in the limestones, immediately below the dolostones of the 'Diagenetic Carbonates'.

The basal contact of the 'Diagenetic Carbonates' is both conformable and laterally transgressive. These dolostones are light grey to yellow weathering, massive bedded, sparsely fossiliferous, vuggy to tight, fine- to coarse-crystalline, commonly bituminous, and dark grey to black, when fresh. They commonly contain dark grey to black chert. Some light grey limestones occur above these dolostones in the core of a syncline, 1.3 km inland of the Boat Harbour–Cape Norman coast. They are the highest beds of the St. George Group recognized in the study area.

Generally, the Catoche Formation is thin and hence probably incomplete. It is also more dolomitic and less fossiliferous than that in the type area. In the Eddies Cove West–Port au Choix type area, it is up to 165-m thick and the 'Diagenetic Carbonates' range between 32 and 40+ m in thickness (Knight, personal communication, 1982; Pratt and James, 1982).

The lower limestone sequence of the Catoche Formation has yielded articulate brachiopods, straight and curved cephalopods, echinoderms (eocrinoid fragments), high- and low-spired gastropods, ostracodes, as well as trilobites and conodonts. To date, the 'Diagenetic Carbonates' have yielded only silicified articulate brachiopods, straight and curved cephalopods, high- and low-spired gastropods, and receptaculitids.

BIOSTRATIGRAPHY

TERMINOLOGY

Range zones as defined by Johnson (1979) and Ludvigsen *et al.* (1986) have been used to set up the trilobite biostratigraphy. The zones are named for their most common and/or distinctive species. The base of each zone is defined by the first appearance of the nominate species. Following Murphy (1977), Johnson (1979) and Ludvigsen *et al.* (1986), the top of each zone is defined by the base of the succeeding zone.

TRILOBITE ZONATION

Watts Bight Formation

To date, only silicified ellesmeroceratid cephalopods and large, low-spired gastropods have been recovered from this unit and it remains unzoned with respect to trilobites.

Boat Harbour and Catoche formations

The basal 45 m of the Lower member of the Boat Harbour Formation has proven to be nonfossiliferous. However, potential for zonation does exists farther south in the vicinity of Eddies Cove West. Here, a low diversity trilobite fauna was collected from the Lower member of the formation, at Fish Point (Boyce, 1983a, page 11).

Three trilobite-based biostratigraphic zones are proposed for the upper 71 m of the Lower member of the Boat Harbour Formation, the Barbace Cove Member of the Boat Harbour Formation, and the Catoche Formation. Following Ludvigsen (1982) for all fauna lists in this section, species that continue from the subjacent (underlying) zone are indicated by a minus sign (-) and species that continue into the superjacent (overlying) zone are indicated by a plus sign (+). The proposed zones, shown in Figure 4 in ascending order, are as follows:

1) *Randaynia saundersi* Zone (9.84 to 66.21 m above the base of the Boat Harbour composite section)

This zone is characterized by the following trilobite species:

-Hystricurus oculilunatus Ross
Hillyardina minuspustulata sp. nov.
Randaynia saundersi gen. et sp. nov.
Hystricurus deflectus Heller
Parahystricurus smithiae sp. nov.
Hillyardina levis sp. nov.
Gen. nov. A. sp. nov. A
Paraplethopeltis seelyi (Whitfield)
Gen. nov. B. sp. nov. A

Assigned collections: Lower member of the Boat Harbour Formation at Boat Harbour, BH-9 to BH-39.

The trilobites of the *Randaynia saundersi* Zone are predominantly hystricurids. *Hystricurus oculilunatus* Ross extends upward from the underlying unzoned strata. However, none of the species range into the overlying zones.

2) *Strigigenalis brevicaudata* Zone (71.80 to 83.88 m above the base of the Boat Harbour composite section)

The base of this zone is defined by the first appearance of the nominate species. The top of the zone is defined by the first appearance of *Strigigenalis caudata* (Billings), which is considered to be the direct evolutionary descendent of *S. brevicaudata*. The zone is characterized by the following trilobite species:

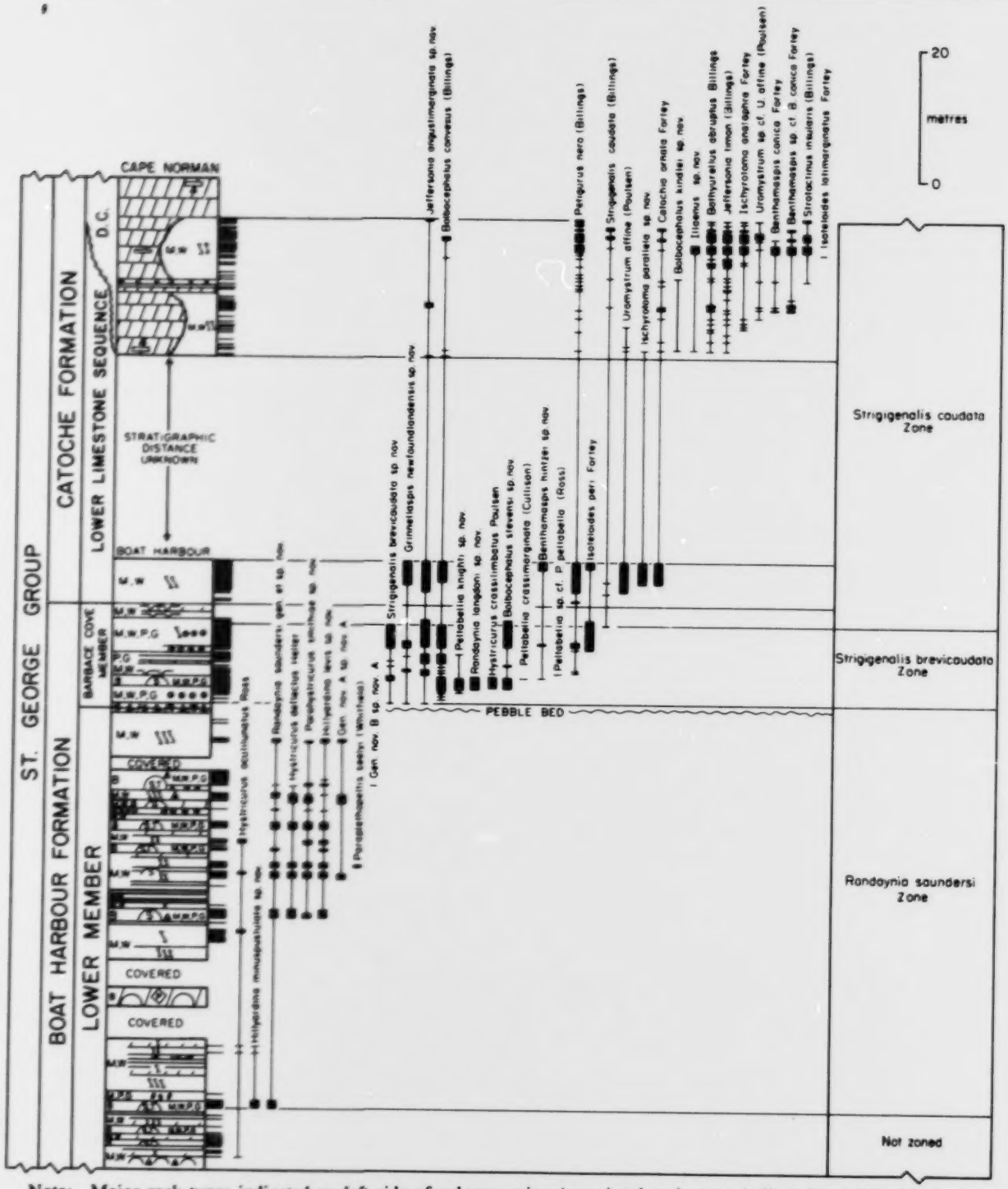
+Strigigenalis brevicaudata sp. nov.
+Grinnellaspis newfoundlandensis sp. nov.
+Jeffersonia angustimarginata sp. nov.
+Bolbocephalus convexus (Billings)
Peltabellia knighti sp. nov.
Randaynia langdoni sp. nov.
Hystricurus crassilimbatus Poulsen
+Bolbocephalus stevensi sp. nov.
Peltabellia crassimarginata (Cullison)
+Benthamaspis hintzei sp. nov.
Peltabellia sp. cf. *P. peltabella* (Ross)
+Petigurus nero (Billings)
+Isoteloides peri Fortey

Assigned collections: Barbace Cove Member of the Boat Harbour Formation at Boat Harbour, BH-40 to BH-93.

The trilobites of the *Strigigenalis brevicaudata* Zone are predominantly bathyurids. None of the species range into the underlying *Randaynia saundersi* Zone.

3) *Strigigenalis caudata* Zone (83.88 to 93.60 m above the base of the Boat Harbour composite section, and 0 to 21.06 m above the base of the Cape Norman section, and 24 to 103 m above the base of Boyce's Port au Choix section *in* Williams *et al.*, 1987, Figure 2).

The base of this composite range zone is defined at Boat Harbour, at the first occurrence of the nominate species. As well as being a stratal event, in the sense of Johnson (1979, page 932), the first appearance of *S. caudata* is also a phyletic event because, as Johnson (1979, page 935) states, 'there is no long sustained diversity increase due to splitting,' the parent species in this case being *S. brevicaudata*. The top of the *S. caudata* range zone is not yet defined and the internal details of the zone remain unclear, because there is no overlap between the Boat Harbour and Cape Norman sections described here and the Port au Choix section. However, data obtained from a continuous section in the vicinity of Eddies



Note: Major rock types indicated on left side of column; minor/associated rock types indicated on right side.

Figure 4. *Biostratigraphic zonation of the Boat Harbour and Catoche formations in the Boat Harbour–Cape Norman study area. See Boyce (1985, Figure 2) and Williams* et al. *(1987, Figure 2) for stratigraphic ranges of trilobites in the upper part of the* Strigigenalis caudata *Zone as developed in the Catoche Formation on Port au Choix Peninsula. Legend modified from Levesque (1977, Figure 81).*

LEGEND (Figure 4)

CARBONATE ROCK TYPES

- Dolostone
- Dolostone, limy
- Limestone
- Limestone, dolomitic

PRIMARY DEPOSITIONAL TEXTURES

- M — Mudstone
- W — Wackestone
- P — Packstone
- G — Grainstone
- B — Boundstone

DIAGENETICALLY ALTERED TEXTURES

- x — Crystalline
- Sucrosic

PARTICLES

- Ooids
- Intraclasts
- Tabular pebbles (conglomerates)
- Chert

BIOTURBATION
(including burrows, trails, etc.)

- Sparsely bioturbated
- Moderately bioturbated
- Extensively bioturbated

ORGANIC BUILDUPS

- Algal mounds
- S — Stromatolite mounds
- T — Thrombolite mounds

FOSSIL COLLECTIONS

- Single sampled horizon
- Sampled interval

SEDIMENTARY STRUCTURES

- Interference ripples
- Symmetric ripples
- Mudcracks

EPIGENETIC STRUCTURES

- Pseudobreccia

DISCONFORMITY

- Base of pebble bed

Cove West (Boyce, 1983a, 1985, 1986) allows all three of these sections to be linked. Preliminary analysis of the Eddies Cove West section, which is not discussed in detail in this study, suggests that the *Strigigenalis caudata* Zone can be divided into at least three widely recognizable subzones, with all the boundaries based on phyletic events.

The *Strigigenalis caudata* Zone is characterized by the following trilobite species:

-*Strigigenalis brevicaudata* sp. nov.
-*Grinnellaspis newfoundlandensis* sp. nov.
-*Jeffersonia angustimarginata* sp. nov.
-*Bolbocephalus convexus* (Billings)
-*Bolbocephalus stevensi* sp. nov.
-*Benthamaspis hintzei* sp. nov.
-*Petigurus nero* (Billings)
-*Isoteloides peri* Fortey
Punka sp. nov. (= *Punka?* sp. indet., Fortey, 1979a)
Petigurus sp. nov. A (= *Petigurus* sp. indet., Fortey, 1979a)
Strigigenalis caudata (Billings)
Uromystrum affine (Poulsen)
Ischyrotoma parallela sp. nov.
Catochia ornata Fortey
Bolbocephalus kindlei sp. nov.
Illaenus sp. nov.
Bathyurellus abruptus Billings
Punka flabelliformis Fortey
Jeffersonia timon (Billings)
Ischyrotoma anataphra Fortey
Uromystrum sp. cf. *U. affine* (Poulsen)
Benthamaspis conica Fortey
Benthamaspis sp. cf. *B. conica* Fortey
Strotactinus insularis (Billings)
Carolinites genacinaca nevadensis Hintze
Isoteloides latimarginatus Fortey
Benthamaspis gibberula (Billings)
Opipeuter sp. cf. *O. angularis* (Young)
Catochia glabra Fortey
Bathyurellus platypus Fortey
Goniotelus? sp. cf. Ross (1951)

Assigned collections: Barbace Cove Member of the Boat Harbour Formation and the lower limestone sequence of the Catoche Formation at Boat Harbour, BH-94 to BH-114; the lower limestone sequence of the Catoche Formation at Cape Norman, CN-1 to CN-38 and the Catoche Formation at Catoche Point on the Port au Choix Peninsula, 24 to 103 m above the base of Boyce's section *in* Williams *et al.*, 1987, Figure 2.

CORRELATIVE FAUNAS IN THE ST. GEORGE GROUP

Since 1976, many additional trilobite collections have been made from the St. George Group outside the Boat Harbour–Cape Norman study area. These collections were made in the following areas: Canada Bay, Hare Bay, Burnt Island, Schooner Island, Brig Bay, St. John Bay, Eddies Cove West, Port au Choix–Back Arm, Port Saunders–Keppel Island, Hawkes Bay–River of Ponds Lake, Bateau Barrens Road, Parson's Pond, Bonne Bay Little Pond and the Port au Port Peninsula. The majority of the collections were made for the first time. The results are summarized in Table 1.

Table 1. Correlative faunas in the St. George Group. Species comparisons are only for those species systematically treated.

TRILOBITE SPECIES	BOAT HARBOUR-CAPE NORMAN	CANADA BAY	HARE BAY	BURNT ISLAND	SCHOONER ISLAND	BRIG BAY	ST. JOHN BAY
Hystricurus oculilunatus	lBHF		lBHF			lBHF	
Hillyardina minuspustulata	lBHF						
Randaynia saundersi	lBHF					lBHF	lBHF
Hystricurus deflectus	lBHF					lBHF	lBHF
Parahystricurus smithiae	lBHF		lBHF				lBHF
Hillyardina levis	lBHF					lBHF	lBHF
Gen. nov. A sp. nov. A	lBHF						
Paraplethopeltis seelyi	lBHF		lBHF			lBHF	
Leiostegium proprium			lBHF				
Gen. nov. B sp. nov. A	lBHF						
Strigigenalis brevicaudata	uBHF, CF		uBHF		uBHF		
Grinnellaspis newfoundlandensis	uBHF, CF		uBHF				
Jeffersonia angustimarginata	uBHF, CF	CF	uBHF	CF	uBHF, CF		CF
Bolbocephalus convexus	uBHF, CF	CF	uBHF, CF	CF	uBHF, CF		CF
Peltabellia knighti	uBHF		uBHF		uBHF		
Randaynia langdoni	uBHF						
Hystricurus crassilimbatus	uBHF						
Bolbocephalus stevensi	uBHF		uBHF		uBHF		
Peltabellia crassimarginata	uBHF						
Benthamaspis hintzei	uBHF, CF				CF		
Peltabellia sp. cf. *P. peltabella*	uBHF						
Petigurus nero	uBHF, CF	CF	CF	CF	CF		CF
Isoteloides peri	uBHF, CF	CF	uBHF		uBHF, CF		CF
Strigigenalis caudata	uBHF, CF				uBHF		CF
Petigurus sp. nov. A		CF					
Uromystrum affine	CF	CF		CF	CF		
Ischyrotoma parallela	CF	CF	uBHF				
Catochia ornata	CF		uBHF				
Bolbocephalus kindlei	CF	CF		CF			
Illaenus sp. nov.	CF	CF	CF	CF	CF		
Bathyurellus abruptus Billings	CF		CF		CF		CF
Jeffersonia timon	CF	CF	CF	CF	CF		
Ischyrotoma anataphra	CF	CF			CF		
Uromystrum sp. cf. *U. affine*	CF		CF				
Benthamaspis conica	CF						CF
Benthamaspis sp. cf. *B. conica*	CF						
Strotactinus insularis	CF			CF			
Isoteloides latimarginatus	CF			CF			

Note: See Fortey (1979a), Boyce (1983, 1985) and Boyce *et al.* (1988) for additional species comparisons of younger Catoche Formation faunas at Port au Choix, Eddies Cove West and Burnt Island. lBHF – Lower member of Boat Harbour Formation; uBHF – Barbace Cove Member of Boat Harbour Formation; CF – Catoche Formation; CBF – Corner Brook Formation.

Canada Bay

Johnson *in* Betz (1939, page 19) identified a cranidium of *Hystricurus* from the St. George Group limestones exposed here, but did not specify its exact location. However, *Hytricurus* alone suggests the presence of the *Randaynia saundersi* Zone.

Beds of the Catoche Formation exposed on Fane Island (= Sprucy Island of Betz, 1939), west of Drummond Island (= David Island of Betz, 1939) in Northeast Arm, have yielded the following trilobites (Boyce, personal communication *in* Knight and Saltman, 1980, pages 19-20):

Bolbocephalus convexus (Billings)
Isoteloides peri Fortey
Jeffersonia angustimarginata sp. nov.
Petigurus nero (Billings)
Uromystrum affine (Poulsen)

These trilobites are indicative of the oldest part of the *Strigigenalis caudata* Zone.

Beds of the Catoche Formation, exposed on the main road to Roddickton as well as on logging roads in the north-central part of the Roddickton map sheet (121/16), have yielded the following trilobites:

Table 1. (Continued)

EDDIES COVE WEST	PORT AU CHOIX-BACK ARM	PORT SAUNDERS-KEPPEL ISLAND	HAWKES BAY	BATEAU BARRENS ROAD	PARSON'S POND	BONNE BAY LITTLE POND	PORT AU PORT
lBHF		lBHF	lBHF				
lBHF			lBHF				
lBHF							
lBHF							
lBHF							
lBHF							
uBHF, CF	uBHF, CF			uBHF			
CF	uBHF, CF	uBHF, CF					
uBHF, CF	uBHF, CF	uBHF, CF					
uBHF, CF	uBHF, CF		CF		CF		uBHF, CF
	uBHF						
uBHF	uBHF, CF						
uBHF, CF	CF						
uBHF, CF	CF		CF				
uBHF							
CF	uBHF, CF		CF		CF		uBHF, CF
uBHF, CF	uBHF, CF	uBHF, CF	CF	uBHF			
CF	CF		CF		CF		
uBHF, CF	CF						
CF	CF		CF				CF
uBHF, CF	CF						
CF	CF						
CF			CF				
CF	CF		CF				
CF	CF		CF		CF		
CF	CF		CF	CF	CF		CF
CF	CF		CF		CF		
CF	CF		CF				
CF	CF						
	CF						
CF	CF		CF	CF		CBF	
CF	CF		CF		CF		

Bolbocephalus convexus (Billings)
Bolbocephalus kindlei sp. nov.
Ilaenus sp. nov.
Ischyrotoma anataphra Fortey
Ischyrotoma parallela sp. nov.
Jeffersonia angustimarginata sp. nov.
Jeffersonia timon (Billings)
Petigurus nero (Billings)
Petigurus sp. nov. A
Uromystrum affine (Poulsen)

These species are indicative of the *Strigigenalis brevicaudata* and *Strigigenalis caudata* zones.

Hare Bay

Murray, *in* Murray and Howley (1881), first reported the occurrence of the *S. brevicaudata* to *S. caudata* Zone trilobite *Petigurus nero* (Billings) in Hare Bay.

Reconnaissance sampling of the Watts Bight, Boat Harbour, and Catoche formations commenced in 1987 on the southern shores of the Brent Islands in Hare Bay (Boyce *et al.*, 1988). Twenty-six previously unsampled horizons in three sections yielded macrofossils. These were also sampled for conodonts. Another 19 conodont samples were taken from horizons lacking macrofossils—chiefly in the Watts Bight and

Boat Harbour formations. These samples have as yet to be analyzed.

The top of the Watts Bight Formation on South Brent Island yielded the trilobite *Parahystricurus* sp. cf. P. sp. I (Ross, 1951; Plate 17, figures 1-3). At Eddies Cove West, this trilobite occurs well below the base of the *Randaynia saundersi* Zone.

Trilobites were recovered for the first time from the Lower member of the Boat Harbour Formation on North Brent Island. The following species were collected:

Hystricurus oculilunatus Ross
Leiostegium proprium sp. nov.
Parahystricurus smithiae sp. nov.
Paraplethopeltis seelyi (Whitfield)

The fauna correlates with that of the *Randaynia saundersi* Zone.

The Barbace Cove Member of the Boat Harbour Formation on North Brent Island yielded the following trilobite species:

Bolbocephalus convexus (Billings)
Bolbocephalus stevensi sp. nov.
?Catochia ornata Fortey
Grinnellaspis newfoundlandensis sp. nov.
Ischyrotoma parallela sp. nov.
Isoteloides peri Fortey
Jeffersonia angustimarginata sp. nov.
Peltabellia knighti sp. nov.
Strigigenalis brevicaudata sp. nov.

The fanuna correlates with that of the *Strigigenalis brevicaudata* and lower *Strigigenalis caudata* zones.

Dr. R.A. Fortey has identified the following *Strigigenalis caudata* Zone trilobites from the basal beds of the conformably overlying Catoche Formation on North Brent Island (N.P. James, personal communication, 1979):

Bolbocephalus convexus (Billings)
Illaenus sp.
Jeffersonia timon (Billings)
Petigurus nero (Billings)

The author has also identified the following, from collections obtained by Dr. R.K. Stevens, from the Catoche Formation of Hare Bay:

Bathyurellus abruptus Billings
?Bolbocephalus sp. indet.
Gen. et sp. indet.
Illaenus sp. nov.
Ischyrotoma sp. indet.
Jeffersonia sp. indet.
Jeffersonia timon (Billings)
Petigurus nero (Billings)
Punka flabelliformis Fortey
Strigigenalis sp. indet.
Uromystrum sp. cf. *U. affine* (Poulsen)

The above fauna also correlates with the *Strigigenalis caudata* Zone.

The Catoche Formation has yielded trilobites at a number of other localities in the Hare Bay area. Beds exposed at the community wharves in Main Brook have yielded *Jeffersonia timon* (Billings). *Petigurus nero* (Billings) and *Uromystrum* sp. cf. *U. affine* (Poulsen) have been collected on the north shore of Pradet Island (Boyce, *in* Stouge, 1981). *Petigurus nero* (Billings) has also been collected on Maria Island. These trilobites, taken together, are indicative of the *Strigigenalis caudata* Zone as well.

Burnt Island

Forty-six trilobite collections have been obtained from the Catoche Formation on the western side of Burnt Island (eastern Pistolet Bay). The following species have been identified (Boyce *et al.*, 1988):

Bathyurellus platypus Fortey
Benthamaspis gibberula (Billings)
?Benthamaspis sp. indet.
Bolbocephalus convexus (Billings)
Bolbocephalus kindlei sp. nov.
?Carolinites sp. indet.
Gignopeltis rarus (Billings)
?Goniotelina sp. indet.
Illaenus sp. nov.
Ischyrotoma sp. indet.
Isoteloides latimarginatus Fortey
Jeffersonia angustimarginata sp. nov.
Jeffersonia timon (Billings)
?Kawina sp. indet.
Peltabellia glandicephalus (Whitfield)
Petigurus nero (Billings)
?Punka sp. indet.
?Raymondaspis sp. indet.
Uromystrum affine (Poulsen)
Uromystrum sp. nov.

The above species are correlative with the upper part of the *Strigigenalis caudata* Zone as exposed at Port au Choix. However, younger faunas may also be present.

Schooner Island

Twenty-nine fossiliferous levels have been sampled on Schooner Island (western Pistolet Bay) for trilobites and conodonts. The collections were obtained on the eastern side

of the island, from the Barbace Cove Member of the Boat Harbour Formation and from the Catoche Formation (Boyce *et. al.*, 1988).

The Barbace Cove Member of the Boat Harbour Formation yielded the following trilobite species:

Bolbocephalus convexus (Billings)
Bolbocephalus stevensi sp. nov.
Isoteloides peri Fortey
Jeffersonia angustimarginata sp. nov.
Peltabellia knighti sp. nov.
Strigigenalis brevicaudata sp. nov.
Strigigenalis caudata (Billings)

This assemblage of trilobite species indicates a correlation with the *Strigigenalis brevicaudata* Zone and the lowest part of the *Strigigenalis caudata* Zone.

The Catoche Formation yielded the following trilobite species:

Bathyurellus abruptus Billings
Benthamaspis hintzei sp. nov.
Bolbocephalus convexus (Billings)
Illaenus sp. nov.
Ischyrotoma anataphra Fortey
Isoteloides peri Fortey
Jeffersonia angustimarginata sp. nov.
Jeffersonia sp. indet.
Jeffersonia timon (Billings)
Petigurus nero (Billings)
Punka sp. nov.
Uromystrum affine (Poulsen)

The above species are indicative of the *Strigigenalis caudata* Zone.

Brig Bay

Trilobites have been collected from the Lower member of the Boat Harbour Formation at a number of localities in the Brig Bay area. *Paraplethopeltis seelyi* (Whitfield) was collected from a thrombolitic lime boundstone bed forming the top of Moyrac Island, just north of Old Ferrolle Island. *Hystricurus deflectus* Heller and *Randaynia saundersi* gen. et sp. nov. were collected at the northern tip of Old Ferrolle Island, whereas *Hillyardina levis* sp. nov., *Hystricurus oculilunatus* Ross and *Randaynia saundersi* gen. et sp. nov. were obtained from the northwest side. *Hystricurus oculilunatus* Ross was also collected at Beach Point on the Dog Peninsula (Boyce, 1979a,b). These trilobites are all indicative of the *Randaynia saundersi* Zone.

St. John Bay

On West Fox Island, limestones of the Lower member of the Boat Harbour Formation yielded the following *Randaynia saundersi* Zone trilobites:

Hillyardina levis sp. nov.
Hystricurus deflectus Heller
Parahystricurus smithiae sp. nov.

Limestones of the Boat Harbour Formation exposed on James Island yielded the following *Randaynia saundersi* Zone species (Boyce, 1985):

Hillyardina levis sp. nov.
Hystricurus deflectus Heller
Parahystricurus smithiae sp. nov.
Randaynia saundersi gen. et sp. nov.

On the northeast tip of eastern Whale Island, Catoche Formation limestones yielded the following *Strigigenalis caudata* Zone trilobites (Boyce, 1985):

Bathyurellus abruptus Billings
Benthamaspis conica Fortey
Bolbocephalus convexus (Billings)
Isoteloides peri Fortey
Jeffersonia angustimarginata sp. nov.
Petigurus nero (Billings)
Strigigenalis caudata (Billings)

Eddies Cove West

Along the coast north of Fish Point and south of Squid Cove, beds assigned by Knight (1983) to the Boat Harbour Formation have yielded the *Randaynia saundersi* Zone trilobite *Hystricurus oculilunatus* Ross in association with rare, straight cephalopods and the planispiral gastropod *Lecanospira*. At Fish Point, the Lower member of the Boat Harbour Formation has yielded the trilobites *Parahystricurus* sp. cf. *P.* sp. I. (Ross) and *?Paraplethopeltis* sp. (Boyce, 1983a, *this study)*. This represents an older, previously unreported fauna.

In the vicinity of Eddies Cove West, at Old Man Cove, an incompletely exposed dolomitized interval occurs at the top of the Lower member of the Boat Harbour Formation. Following Knight (1983), this dolomitized interval is considered to be stratigraphically analogous to the interval at Boat Harbour containing the 'pebble bed' disconformity of Knight (1977b, 1978).

At Eddies Cove West, 22 fossiliferous horizons were sampled in the Lower member of the Boat Harbour Formation below the Old Man Cove dolomitized interval. The following species have been identified (Boyce, 1983a, 1985):

Hystricurus oculilunatus Ross
Parahystricurus smithiae sp. nov.
Leiostegium proprium sp. nov.
Rossaspis sp. cf. *R. pliomeris* Demeter (1973; Plate 2, figures 1-4)
Paraplethopeltis seelyi (Whitfield)
Hystricurus deflectus Heller
Randaynia saundersi gen. et sp. nov.
Hillyardina levis sp. nov.

Associated with these trilobites are brachiopods *(Diaphelasma,* orthids), cephalopods *(Basslerocerас),* echinoderms (eocrinoid debris) and gastropods *(Ecculiomphalus, Lecanospira).* The same fauna occurs below the Boat Harbour 'pebble bed' in the *Randaynia saundersi* Zone.

Above the Old Man Cove dolomitized interval, 10 fossiliferous horizons were sampled in the Barbace Cove Member of the Boat Harbour Formation. The following species have been identified:

Bolbocephalus stevensi sp. nov.
Strigigenalis brevicaudata sp. nov.
Isoteloides peri Fortey
Bolbocephalus convexus (Billings)
Peltabellia crassimarginata (Cullison)
Benthamaspis hintzei sp. nov.
Petigurus sp. nov. A
Jeffersonia angustimarginata sp. nov.
Ischyrotoma parallela sp. nov.
Peltabellia sp. cf. *P. peltabella* (Ross)

Essentially the same fauna occurs above the Boat Harbour 'pebble bed' in the *Strigigenalis brevicaudata* and lower *Strigigenalis caudata* zones.

In the Eddies Cove West area, 52 fossiliferous horizons were sampled in the Catoche Formation. The following species have been identified:

Strigigenalis brevicaudata sp. nov.
Isoteloides peri Fortey
Bolbocephalus convexus (Billings)
Peltabellia crassimarginata (Cullison)
Benthamaspis hintzei sp. nov.
Petigurus sp. nov. A
Jeffersonia angustimarginata sp. nov.
Ischyrotoma parallela sp. nov.
Peltabellia willistoni Lochman
Petigurus groenlandicus Poulsen
Uromystrum affine (Poulsen)
Petigurus nero (Billings)
Grinnellaspis newfoundlandensis sp. nov.
Catochia ornata Fortey
Strigigenalis caudata (Billings)
Punka sp. nov. (= *Punka?* sp. indet. Fortey, 1979a)
Benthamaspis conica Fortey
Ischyrotoma anataphra Fortey
Punka flabelliformis Fortey
Bathyurellus abruptus Billings
Jeffersonia timon (Billings)
Isoteloides latimarginatus Fortey
Strotactinus insularis (Billings)
Benthamaspis gibberula (Billings)
Illaenus sp. nov.
Bolbocephalus kindlei sp. nov.
Uromystrum sp. cf. *U. affine* (Poulsen)
Bathyurellus platypus Fortey
Catochia glabra Fortey

Most of the species also occur in the *Strigigenalis brevicaudata* and *Strigigenalis caudata* zones above the Boat Harbour 'pebble bed' and at Cape Norman.

Port au Choix–Back Arm

At Barbace Point on the north side of Barbace Cove, Port au Choix Peninsula, a dolomitized interval occurs at the top of the Lower member of the Boat Harbour Formation. The author concurs with Knight (1983), and considers this interval to be stratigraphically equivalent to the incompletely exposed Old Man Cove dolomitized interval at Eddies Cove West and the 'pebble bed' interval at Boat Harbour. In the Barbace Point dolomitized interval, Knight (1983) has identified a thin chert–dolostone breccia resting on dolomitized stromatolite mounds that is considered to be a disconformity surface.

Above the breccia at Barbace Point, 8 fossiliferous horizons were sampled in the Barbace Cove Member of the Boat Harbour Formation. The following *Strigigenalis brevicaudata* Zone trilobite species were collected:

Peltabellia knighti sp. nov.
Grinnellaspis newfoundlandensis sp. nov.
Isoteloides peri Fortey
Bolbocephalus convexus (Billings)
Jeffersonia angustimarginata sp. nov.
Petigurus nero (Billings)
Strigigenalis brevicaudata sp. nov.

At Barbace Point, on the north side of Barbace Cove, Port au Choix Peninsula, 7 fossiliferous horizons were sampled in the Catoche Formation. The following species have been identified:

Grinnellaspis newfoundlandensis sp. nov.
Isoteloides peri Fortey
Bolbocephalus convexus (Billings)
Jeffersonia angustimarginata sp. nov.
Petigurus nero (Billings)
Strigigenalis brevicaudata sp. nov.
Ischyrotoma parallela sp. nov.
Uromystrum affine (Poulsen)
Benthamaspis hintzei sp. nov.
Petigurus sp. nov. A
Petigurus groenlandicus Poulsen
Bolbocephalus stevensi sp. nov.
Peltabellia willistoni Lochman
Peltabellia crassimarginata (Cullison)
Strigigenalis caudata (Billings)
Benthamaspis conica Fortey
Uromystrum sp. cf. *U. affine* (Poulsen)

These species are indicative of the *Strigigenalis brevicaudata* and *Strigigenalis caudata* zones.

At Catoche Point, on the south side of Barbace Cove, Fortey (1979a) and Boyce (1985, 1986) sampled 13 and 73

fossiliferous horizons, respectively, in the Catoche Formation. The following species have been identified:

Isoteloides peri Fortey
Bolbocephalus convexus (Billings)
Jeffersonia angustimarginata sp. nov.
Petigurus nero (Billings)
Strigigenalis brevicaudata sp. nov.
Petigurus sp. nov. A
Strigigenalis caudata (Billings)
Benthamaspis conica Fortey
Uromystrum sp. cf. *U. affine* (Poulsen)
Punka sp. nov.
Ischyrotoma anataphra Fortey
Catochia ornata Fortey
Bathyurellus abruptus Billings
Punka flabelliformis Fortey
Jeffersonia timon (Billings)
Strotactinus insularis (Billings)
Carolinites genacinaca nevadensis Hintze
Isoteloides latimarginatus Fortey
Benthamaspis gibberula (Billings)
Illaenus sp. nov.
Opipeuter sp. cf. *O. angularis* Young
Catochia glabra Fortey
Bathyurellus platypus Fortey
Goniotelus? sp. cf. Ross (1951)

These species are indicative of the *Strigigenalis caudata* Zone.

Querré and Savage islands in Back Arm, Port au Choix were also sampled for trilobites. Limestones of the Catoche Formation exposed on Querré Island yielded the following *Strigigenalis caudata* Zone species:

Bathyurellus abruptus Billings
Benthamaspis conica Fortey
Benthamaspis gibberula (Billings)
Bolbocephalus convexus (Billings)
Isoteloides peri Fortey
Jeffersonia timon (Billings)
Petigurus sp. nov. A
Petigurus nero (Billings)
Punka flabelliformis Fortey
Strigigenalis caudata (Billings)
Strotactinus insularis (Billings)

On Savage Island, limestones of the Barbace Cove Member of the Boat Harbour Formation yielded the following *Strigigenalis brevicaudata* Zone species:

Isoteloides peri Fortey
Bolbocephalus stevensi sp. nov.
Jeffersonia angustimarginata sp. nov.

The overlying Catoche Formation limestones yielded:

Benthamaspis hintzei sp. nov.
Benthamaspis conica Fortey
Bolbocephalus convexus (Billings)
Ischyrotoma parallela sp. nov.
Jeffersonia angustimarginata sp. nov.
Peltabellia willistoni Lochman
Grinnellaspis newfoundlandensis sp. nov.

These species are indicative of the *Strigigenalis brevicaudata* to lower *Strigigenalis caudata* zones.

Port Saunders–Keppel Island

Fossiliferous beds of the Boat Harbour Formation are exposed in a roadside quarry along the Viking Trail, 4 km north of the junction with the road to Port Saunders. Here, the *Randaynia saundersi* Zone trilobite *Hystricurus oculilunatus* Ross and the planispiral gastropod *Lecanospira* were collected (Boyce, 1983a).

On Keppel Island, south of Port Saunders, limestones of the Barbace Cove Member of the Boat Harbour Formation, and the Catoche Formation yielded the following *Strigigenalis brevicaudata* Zone to lower *Strigigenalis caudata* Zone species:

Grinnellaspis newfoundlandensis sp. nov.
Isoteloides peri Fortey
Peltabellia willistoni Lochman
Petigurus groenlandicus Poulsen
Jeffersonia angustimarginata sp. nov.

Hawkes Bay–River of Ponds Lake

Knight and Boyce (1984) and Knight (1985) mapped two belts of St. George Group rocks south of Hawkes Bay, east of River of Ponds Lake and west of Eastern Blue Pond.

From the Lower member of the Boat Harbour Formation, the following *Randaynia saundersi* Zone trilobites were obtained:

Hystricurus oculilunatus Ross
Randaynia saundersi gen. et sp. nov.

The Catoche Formation yielded the following *Strigigenalis brevicaudata* Zone and *Strigigenalis caudata* Zone trilobites:

Bathyurellus abruptus Billings
Bathyurellus platypus Fortey
Benthamaspis gibberula (Billings)
Bolbocephalus convexus (Billings)
Bolbocephalus kindlei sp. nov.
Illaenus sp. nov.
Ischyrotoma anataphra Fortey
Isoteloides peri Fortey
Petigurus nero (Billings)
Peltabellia willistoni Lochman
Punka flabelliformis Fortey
Strotactinus insularis (Billings)
Uromystrum affine (Poulsen)
Uromystrum sp. cf. *U. affine* (Poulsen)

Limestones of the Catoche Formation exposed at Hawkes Harbour and westward along the southern shore of Hawkes Bay (Knight and Boyce, 1984) have yielded the following trilobite species:

Benthamaspis hintzei sp. nov.
Isoteloides peri Fortey
Peltabellia willistoni Lochman
Petigurus sp. nov. A
Strigigenalis caudata (Billings)
Benthamaspis conica Fortey
Petigurus nero (Billings)
Uromystrum affine (Poulsen)
Punka flabelliformis Fortey
Benthamaspis gibberula (Billings)
Isoteloides latimarginatus Fortey
Jeffersonia timon (Billings)

These species are indicative of the *Strigigenalis brevicaudata* and *Strigigenalis caudata* zones.

Bateau Barrens Road

Knight (1985) discovered another exposure of the Boat Harbour Formation 'pebble bed' along Bateau Barrens Road (Figure 1). Dolomitic limestones of the Barbace Cove Member of the Boat Harbour Formation, a short distance above this horizon in two locations, yielded abundant articulate brachiopods and the following *Strigigenalis brevicaudata* Zone trilobites (Boyce, 1985):

Isoteloides peri Fortey
Strigigenalis brevicaudata sp. nov.

Stratigraphically high exposures of the Catoche Formation along the Bateau Barrens Road yielded the following *Strigigenalis caudata* Zone species:

Benthamaspis gibberula (Billings)
Jeffersonia timon (Billings)
Punka flabelliformis Fortey
Strotactinus insularis (Billings)

Parson's Pond

At the eastern end of Parson's Pond, limestones of the Catoche Formation have yielded the following *Strigigenalis caudata* Zone trilobites:

Bathyurellus abruptus Billings
Benthamaspis gibberula (Billings)
Bolbocephalus convexus (Billings)
Ischyrotoma anataphra Fortey
Jeffersonia sp.
Isoteloides latimarginatus Fortey
Jeffersonia timon (Billings)
Petigurus nero (Billings)
Strigigenalis caudata (Billings)
Punka flabelliformis Fortey
Ischyrotoma sp.

In addition, silicified articulate brachiopods and a cephalopod or echinoderm fragment were collected (Boyce, 1981b, pages 15-16).

Bonne Bay Little Pond

Approximately 2.1 km west-northwest of Bonne Bay Little Pond, limestones assigned by Boyce (1981a) to the Corner Brook Formation of Lilly (1961, 1963) have yielded the following *Strigigenalis caudata* Zone trilobites (Boyce, 1980):

Benthamaspis sp. indet.
Strotactinus insularis (Billings).

Port au Port Peninsula

Beds assignable to the Barbace Cove Member of the uppermost part of the Boat Harbour Formation (formerly the Isthmus Bay Formation of James *et al.*, 1980 and Pratt and James, 1982) and the lowermost part of the Catoche Formation are exposed just southwest of the southern bar of The Gravels. Here, the following trilobites were collected:

Bolbocephalus convexus (Billings)
Isoteloides sp.
Jeffersonia sp.
Petigurus nero (Billings)

Whittington and Kindle (1969, page 658) also report *Peltabellia* sp. from this locality. These trilobites probably represent the youngest part of the *Strigigenalis brevicaudata* Zone and/or the oldest part of the *Strigigenalis caudata* Zone.

Limestones of the Catoche Formation exposed north of Pigeon Head in Lower Cove have yielded the following trilobites:

Bathyurellus sp.
Bolbocephalus convexus (Billings)
Ischyrotoma sp.
Isoteloides sp.
Jeffersonia timon (Billings)
Petigurus nero (Billings)
Uromystrum affine (Poulsen)

Whittington and Kindle (1969, page 658) also report *Strigigenalis* sp. from here. These species taken together are suggestive of the *Strigigenalis caudata* Zone.

CORRELATIVE FORMATIONS IN PLATFORM FACIES

Several of the species found in the Boat Harbour and Catoche formations also occur in Early Ordovician platform facies rocks found elsewhere in North America and northwestern Europe. The common species and their occurrences are summarized in Table 2 and below. Pertinent conodont information, where available, is also mentioned in the text below.

Northwest Scotland

Fortey (1986, page 19) has identified *Petigurus nero* (Billings) and *Jeffersonia timon* (Billings) from the Durness Group.

Northern Spitsbergen

Fortey and Bruton (1973, page 2232) report *Bathyurellus abruptus* Billings from the Nordporten Member of the Kirtonryggen Formation of northern Spitsbergen. Fortey (personal communication, 1985) also reports the presence of *Punka flabelliformis* Fortey and *Petigurus nero* (Billings).

Ellesmere Island, Arctic Canada

Poulsen (1946, page 372; Plate XXII, figure 18) described the *Strigigenalis brevicaudata* Zone species *Hystricurus crassilimbatus* Poulsen from the Canyon Elv Formation (Peel and Cowie, 1979) exposed at Cape Steven and Scoresby Bay. Poulsen (1946; Plate XXIII, figure 10) also illustrated an incomplete pygidium of the *Strigigenalis brevicaudata* to *Strigigenalis caudata* Zone trilobite *Jeffersonia angustimarginata* from the Canyon Elv Formation exposed at Scoresby Bay (Poulsen, 1946; Plate XXIV, figure 2, locality 9). There, it is associated with *Grinnellaspis feildeni* (Poulsen, 1946; Plate XXII, figures 8, 9), a species closely resembling, but not identical to *G. newfoundlandensis*.

The Canyon Elv Formation east of Ellesmere Island in Washington Land, northern Greenland contains the conodont *Oepikodus communis* (Ethington and Clark) (Stouge, 1982). In the study area, this species first appears at the base of the Catoche Formation (Stouge, 1982, Figure 3), 3.10 m above the base of the *Strigigenalis caudata* Zone; it continues to the top of this zone.

Poulsen (1946; Plate XXII, figures 14-16) also illustrated an incomplete cranidium of *Benthamaspis problematica* Poulsen, 1946 from the Nunatami Formation (Poulsen, 1927) exposed at Cape Steven (Poulsen, 1946; Plate XXIV, figure 2, locality 6). Fortey (1979a, page 100) tentatively synonymized this species with the *Strigigenalis caudata* Zone species *Benthamaspis gibberula* (Billings), an assignment with which this author agrees. Among the trilobites associated with *Benthamaspis problematica* is a species of *Jeffersonia* (= Gen et sp. indet II Poulsen, 1946; page 329; Plate XXIII, figures 6-9 only) closely resembling and possibly identical to the *Strigigenalis caudata* Zone species *Jeffersonia timon* (Billings).

Greenland

Poulsen (1937, pages 47-48; Plate 5, figures 5-8) originally described the *Strigigenalis brevicaudata* Zone trilobite *Hystricurus crassilimbatus* Poulsen from the Cape Weber Formation (Poulsen, 1930; Cowie and Adams, 1957; Peel and Cowie, 1979). It was collected from Cape Weber and the upper end of Devon Canyon in east-central Greenland.

The *Strigigenalis caudata* Zone trilobite *Uromystrum affine* (Poulsen), which generally occurs in the basal beds of the Catoche Formation, was originally described by Poulsen (1937, page 55; Plate 7, figures 6, 7) from the eastern part of the anticline on the south coast of Ella Island in east-central Greenland. Here, the Cape Weber Formation also yielded *Bolbocephalus groenlandicus* Poulsen (1937, pages 48-49; Plate 5, figures 9-13), which is synonymized with *Bolbocephalus convexus* (Billings) of the *Strigigenalis brevicaudata* and *Strigigenalis caudata* zones.

The *Strigigenalis caudata* Zone species *Bolbocephalus kindlei* sp. nov. also occurs in the Cape Weber Formation of east-central Greenland. Poulsen (1937; Plate 8, figure 2) illustrated a specimen from the eastern part of the anticline on the south coast of Ella Island.

Fortey (1986) illustrated the following *Strigigenalis caudata* Zone species from the Wandel Valley Formation (Christie and Peel, 1977) of northeastern Greenland:

Bathyurellus abruptus Billings
Benthamaspis conica Fortey
Ischyrotoma anataphra Fortey
Jeffersonia angustimarginata sp. nov.
Petigurus nero (Billings)
Punka flabelliformis Fortey

Mingan Islands, Quebec, Canada

Bolbocephalus convexus (Billings) and *Strigigenalis caudata* (Billings) have been identified by Drs. T.E. Bolton (Geological Survey of Canada) and F.C. Shaw (Lehman College) from the Romaine Formation of the Mingan Islands, Quebec (T.E. Bolton, personal communications, 1985, 1986), and are indicative of the *Strigigenalis caudata* Zone.

Nowlan (1981, page 67) reported *Glyptoconus (='Scolopodus') quadraplicatus* and *'Panapanderodus' (='Scolopodus') gracilis*, *Eucharodus (= 'Drepanodus') parallelus* and *Oepikodus communis* from the Romaine Formation. The first three species occur in both the *Strigigenalis brevicaudata* and *Strigigenalis caudata* zones in western Newfoundland but *Oepikodus communis* only occurs in the *Strigigenalis caudata* Zone.

The cephalopod species *Protocycloceras lamarcki* (Billings), which is found in the *Strigigenalis caudata* Zone beds of the Catoche Formation at Cape Norman, also occurs in the Romaine Formation on the Mingan Islands (Billings, 1865).

Southeastern Ontario, Canada

Ludvigsen (1979a,b) identified and illustrated the *Strigigenalis brevicaudata* to *Strigigenalis caudata* Zone species *Bolbocephalus convexus* (Billings) from the lower sandy division of the Oxford Formation in southeastern Ontario.

Table 2. Correlative formations in platform facies.

TRILOBITE SPECIES	WESTERN NEWFOUNDLAND	NORTHWEST SCOTLAND	NORTHERN SPITSBERGEN	ELLESMERE ISLAND	GREENLAND
Hystricurus oculilunatus	Boat Harbour Fm. (Lower mbr.)				
Jeffersonia angustimarginata	Boat Harbour Fm. (Barbace Cove Mbr.), Catoche Fm.			Canyon Elv Fm.	Wandel Valley Fm.
Bolbocephalus convexus	Boat Harbour Fm. (Barbace Cove Mbr.), Catoche Fm.				Cape Weber Fm.
Peltabelia knighti	Boat Harbour Fm. (Barbace Cove Mbr.)				
Hystricurus crassilimbatus	Boat Harbour Fm. (Barbace Cove Mbr.)			Canyon Elv Fm.	Cape Weber Fm.
Bolbocephalus stevensi	Boat Harbour Fm. (Barbace Cove Mbr.), Catoche Fm.				
Petigurus nero	Boat Harbour Fm. (Barbace Cove Mbr.), Catoche Fm.	Durness Gp.	Kirtonryggen Fm. (Nordporten Mbr.)		Wandel Valley Fm.
Isoteloides peri	Boat Harbour Fm. (Barbace Cove Mbr.), Catoche Fm.				
Strigigenalis caudata	Boat Harbour Fm. (Barbace Cove Mbr.), Catoche Fm.				
Petigurus sp. nov. A	Boat Harbour Fm. (Barbace Cove Mbr.), Catoche Fm.				
Uromystrum affine	Catoche Fm.				Cape Weber Fm.
Bolbocephalus kindlei	Catoche Fm.				Cape Weber Fm.
Bathyurellus abruptus	Catoche Fm.		Kirtonryggen Fm. (Nordporten Mbr.)		Wandel Valley Fm.
Punka flabelliformis	Catoche Fm.		Kirtonryggen Fm. (Nordporten Mbr.)		Wandel Valley Fm.
Jeffersonia timon	Catoche Fm.	Durness Gp.			
Ischyrotoma anataphra	Catoche Fm.				Wandel Valley Fm.
Benthamaspis conica	Catoche Fm.				Wandel Valley Fm.
Benthamaspis gibberula	Catoche Fm.			Nunatami Fm.	

Greggs and Bond (1971, Table 1) and Bond and Greggs (1976, pages 24, 25) report the following conodont species from the Oxford Formation:

Acontiodus staufferi Furnish
Distacodus rhombicus Lindström = *?Acodus* sp. 3 of Ethington and Clark, (1981)
Drepanodus homocurvatus Lindström = *Drepanodus concavus* (Branson and Mehl) of Kennedy (1980)
Drepanodus sp. 1 (Ethington and Clark, 1981)
Drepanodus simplex Branson and Mehl s.f. = *Eucharodus parallelus* (Branson and Mehl) s.f. (Kennedy, 1980; Ethington and Clark, 1981)
"Oistodus" inaequalis Pander s.f.
Oneotodus variabilis Lindström
Scolopodus cornutiformis Branson and Mehl = *Oneotodus costatus* Ethington and Brand of Kennedy (1980) and aff. *Oneotodus simplex* (Furnish) of Ethington and Clark (1981)
Glyptoconus (=Scolopodus) quadraplicatus (Branson and Mehl)
Ulrichodina prima Furnish = *Ulrichodina abnormalis* (Furnish) of Ethington and Clark (1981)

These species also occur in the Barbace Cove Member of the Boat Harbour Formation and in the lower limestone sequence of the Catoche Formation (Barnes and Tuke, 1970, Table 1; Stouge, 1982, Figure 3; Stouge *in* Stouge and Boyce, 1983, Figure 2.2). Like *Bolbocephalus convexus*, they are *Strigigenalis brevicaudata* to *Strigegenalis caudata* Zone species.

The cephalopod *Protocycloceras lamarcki* (Billings) also occurs in the Oxford Formation in Marlborough and Oxford townships (Car and Grenville counties, respectively) in southeastern Ontario (Billings, 1865). In the study area, it is found in the *Strigigenalis caudata* Zone beds of the Catoche Formation at Cape Norman.

Table 2. (Continued)

MINGAN ISLANDS	EASTERN ONTARIO	PENNSYLVANIA	CENTRAL COLORADO	NORTH DAKOTA	BRITISH COLUMBIA
			Manitou Fm.		McKay Gp.
		Axemann Limestone			
Romaine Fm.	Oxford Fm.				
		Axemann Limestone			
				Deadwood Fm.	
		Axemann Limestone			
		Axemann Limestone, Rockdale Run Fm.			
Romaine Fm.		Axemann Limestone			
		Axemann Limestone			
				Deadwood Fm.	

Pennsylvania, USA

Sando (1958; Plate 2, figures 33-35) illustrated *Isoteloides* cf. *I. flexus* Hintze from the Rockdale Run Formation near Chambersburg, Pennsylvania. According to Fortey (1979b, page 38), this species is probably identical to the *Strigigenalis brevicaudata* to *Strigigenalis caudata* Zone species *Isoteloides peri* Fortey.

Lees (1967; Plate 12, figures 1-10, 12-15) illustrated several Early Ordovician trilobite species from the Axemann Limestone of central Pennsylvania. These have been synonymized *(this study)* with the following western Newfoundland forms:

Peltabellia knighti sp. nov.
Bolbocephalus stevensi sp. nov.
Petigurus sp. nov. A
Jeffersonia angustimarginata sp. nov.
Isoteloides peri Fortey
Strigignelis caudata (Billings)

The Axemann Limestone correlates with the *Strigigenalis brevicaudata* Zone and the lower part of the *Strigigenalis caudata* Zone of western Newfoundland, based on the presence of the above species.

Central Colorado, USA

Berg and Ross (1959, page 112; Plate 21, figure 2) illustrated the *Randaynia saundersi* Zone trilobite *Hystricurus oculilunatus* Ross from the Manitou Formation in Williams Canyon near Colorado Springs. Ethington and Clark (1981, page 9) report that the same beds have yielded the conodont *Macerodus dianae* Fahraeus and Nowlan, 1978, which also occurs in the *Randaynia saundersi* Zone.

North Dakota, USA

Lochman (1966, page 533, Plate 65, figure 41) described the *Strigigenalis brevicaudata* Zone species *Hystricurus crassilimbatus* Poulsen from subsurface beds of the Deadwood Formation in the Williston Basin of western North Dakota.

Oculomagnus obreptus Lochman (1966, pages 541-542; Plate 62, figures 1-7) also occurs in the subsurface beds of the Deadwood Formation in North Dakota. Fortey (1979a, page 102) assigned several specimens illustrated by Lochman (1966; Plate 62, figures 1,2 and 4) to the lower *Strigigenalis caudata* Zone species *Benthamaspis conica* Fortey, assignments with which the author agrees.

British Columbia, Canada

Kobayashi (1955, pages 452-454; Plate VI, figure 4; Plate IX, figure 2) illustrated *Vermilionites bisulcatus* gen. et sp. nov. from the Lower Ordovician McKay Group of British Columbia, which is synonymized with the *Randaynia saundersi* Zone trilobite *Hystricurus oculilunatus* Ross.

CORRELATION WITH THE IBEXIAN TRILOBITE AND CONODONT ZONATIONS

Ross and Hintze, *in* Ross *et al.* (1982, pages 5-7 and 7-10, respectively) have recently championed the erection of the Ibexian Series to replace the traditionally accepted Canadian Series. Whether or not the Ibexian Series is eventually accepted, the Ibexian trilobite zonation of Ross (1951) and Hintze (1953) is the standard reference for Early Ordovician trilobite faunas of North America. Ethington and Clark (1981) have also recently proposed subdivisions for conodonts of the Ibex area, relative to the trilobite zones. These subdivisions, which replaced earlier informally proposed 'faunas' (Ethington and Clark, 1971), were designated as 'intervals' rather than zones, pending confirmation from investigations in other areas before defining more formal zones (Hintze *in* Ross *et al.*, 1982, page 9).

Table 3 and Figure 5 summarize the ranges of those trilobite and conodont species in the Ibexian reference section that also occur in the Boat Harbour and Catoche formations. What is immediately obvious upon comparison of the ranges of the two groups, is that individual trilobite species have much shorter ranges than individual conodont species. With the exception of *Macerodus dianae*, which ranges through two trilobite zones, the remaining conodont species range between four and eleven trilobite zones (see Ethington and Clark, 1981, Figure 3). The longest ranging trilobite species in Figure 5, *Hystricurus oculilunatus*, ranges through only two trilobite zones; the remainder have ranges no greater than half a trilobite zone. The shorter trilobite ranges could be construed as indicating that trilobites were more susceptible to environmental factors than conodonts. However, Barnes and Fahraeus (1975) have shown that conodonts were quite strongly environmentally controlled. Furthermore, Fortey and Barnes (1977) have found that conodont communities in the Arenig–Llanvirn of Spitsbergen paralleled those of the trilobites. Harris and Repetski (see Ross *et al.*, 1982, page 3) have also shown that conodont distribution in many of the same intervals as those covered by Ethington and Clark (1981), are controlled by determinable environmental factors to such an extent that some of the stratigraphic ranges of fossils differ from place to place.

To summarize, the shorter ranges of the Ibexian trilobites are considered to be indicative of a higher evolutionary rate, rather than environmental control. Consequently, the Ibexian trilobite zonation of Ross (1951) and Hintze (1953) promises a greater degree of resolution as a biostratigraphic standard. However, the informal conodont zonation of Ethington and Clark (1981) remains the best standard where trilobites are absent. In this study, primary reliance is placed on specific correlation of the trilobites; secondary reliance is placed on specific correlation of the conodont assemblages obtained by Barnes and Tuke (1970), Stouge (1982) and Stouge *in* Stouge and Boyce (1983).

Figure 6 shows the range comparison and correlation of the trilobite–conodont species associations common to Ibex, Utah and western Newfoundland. The correlations are discussed further in the text. Figure 6 also shows the relation of Stouge's (1982) conodont faunas to the trilobite zones proposed in this study.

Hystricurus oculilunatus Ross, a characteristic species of the *Randaynia saundersi* Zone, ranges through most of Ibexian trilobite Zone E and the bottom half of Zone F (Hintze, 1953; Terrell, 1973). The correlation of the *Randaynia saundersi* Zone with Ibexian zones E and F is supported by the common presence of the conodont species *'Parapanderodus' gracilis* (Ethington and Clark) and *Macerodus dianae* Fahraeus and Nowlan. In the study area, they occur together through most of the *Randaynia saundersi* Zone to the base of the 'pebble bed'. *Macerodus dianae* does not occur above this horizon. The mutual occurrence of *'P.' gracilis* and *M. dianae* below the 'pebble bed' suggests that most of this interval is no younger than latest Zone F. In the Ibexian sequence, the two species only range together from latest Zone E to latest Zone F.

In the study area, *Benthamaspis hintzei* sp. nov. ranges through most of the *Strigigenalis brevicaudata* Zone to the lowermost part of the *Strigigenalis caudata* Zone. In the Ibexian sequence, this species occurs slightly above the lower one-fifth of Zone G_2. This suggests that the *S. brevicaudata* Zone lies totally within Zone G_2 and that the base of the *S. caudata* Zone also occurs within Zone G_2. The associated conodont species *Eucharodus parallelus* (Branson and Mehl), *Drepanodus concavus* (Branson and Mehl), *Acodus* sp. 3 of Ethington and Clark (1981), *'Oistodus' inaequalis* Pander, *Ulrichodina abnormalis* (Branson and Mehl), *Scolopodus multicostatus* Barnes and Tuke, *Glyptoconus quadraplicatus* (Branson and Mehl), *Oneotodus costatus* Ethington and Brand, *'Parapanderodus' gracilis* (Ethington and Clark), *Drepanodus? gracilis* (Branson and Mehl), *Tropodus comptus* (Branson and Mehl) and *'Scolopodus' emarginatus* Barnes and Tuke, support this correlation. In the Ibexian sequence, these species do not occur together below the lower third of Zone G_2.

Barnes and Tuke (1970) were the first to analyze the limestones of the St. George Group for conodonts. They sampled two horizons in the Barbace Cove Member of the

Table 3. Ibexian trilobite and conodont species common to western Newfoundland.

TRILOBITE SPECIES	IBEXIAN ZONAL RANGE	WESTERN NEWFOUNDLAND ZONAL RANGE
Hystricurus oculilunatus	Zone E to Zone F	to *Randaynia saundersi* Zone
Petigurus sp. nov. A (= *Petigurus* sp. indet. of Fortey, 1979a)	Zone G_2?	*Strigigenalis brevicaudata* Zone to *Strigigenalis caudata* Zone
Benthamaspis hintzei	Zone G_2	*Strigigenalis brevicaudata* Zone to *Strigigenalis caudata* Zone
Benthamaspis gibberula	Zone H	*Strigigenalis caudata* Zone
Bolbocephalus kindlei	Zone H	*Strigigenalis caudata* Zone
Carolinites genacinaca nevadensis	Zone H	*Strigigenalis caudata* Zone
CONODONT SPECIES		
Eucharodus parallelus	Zone B to Zone L	*Strigigenalis brevicaudata* Zone to *Strigigenalis caudata* Zone
Drepanodus concavus	Zone D to Zone J	*Strigigenalis brevicaudata* Zone to *Strigigenalis caudata* Zone
Glyptoconus quadraplicatus	Zone D to Zone I	*Strigigenalis brevicaudata* Zone to *Strigigenalis caudata* Zone
"Parapanderodus" gracilis	Zone E to Zone M	*Randaynia saundersi* Zone to *Strigigenalis caudata* Zone
Macerodus dianae	Zone E to Zone F	*Randaynia saundersi* Zone
Oneotodus costatus	Zone F to Zone I	*Strigigenalis brevicaudata* Zone to *Strigigenalis caudata* Zone
Acodus sp. of Ethington and Clark (1981)	Zone F to Zone G_2	*Strigigenalis brevicaudata* Zone
"Oistodus" inaequalis	Zone G_1 to Zone J	*Strigigenalis brevicaudata* Zone to *Strigigenalis caudata* Zone
Ulrichodina abnormalis	Zone G_1 to Zone I	*Strigigenalis brevicaudata* Zone
Drepanodus gracilis	Zone G_1 to Zone I	*Strigigenalis brevicaudata* Zone to *Strigigenalis caudata* Zone
Tropodus comptus	Zone G_1 to Zone J	*Strigigenalis brevicaudata* Zone to *Strigigenalis caudata* Zone
Scolopodus multicostatus	Zone G_2	*Strigigenalis brevicaudata* Zone
"Scolopodus" emarginatus	Zone G_2 to Zone J	*Strigigenalis brevicaudata* Zone to *Strigigenalis caudata* Zone
Oepikodus communis	Zone G_2 to Zone K	*Strigigenalis caudata* Zone
Eucharodus toomeyi	Zone H to Zone I	*Strigigenalis brevicaudata* Zone to *Strigigenalis caudata* Zone

Note: Ibexian trilobite data from Hintze (1953), Terrell (1973) and Young (1973); conodont data from Ethington and Clark (1981). Western Newfoundland trilobite data from Boyce (1979a,b, 1983a,b, 1985, 1986, *this study*), Fortey (1979a), Boyce *in* Stouge and Boyce (1983) and Williams *et al.* (1987); conodont data from Barnes and Tuke (1970), Stouge (1982) and Stouge *in* Stouge and Boyce (1983).

Boat Harbour Formation. Their geographic locations are shown in Figure 3.

Tuke *in* Barnes and Tuke (1970, page 80) reported the following fossils from the same outcrops as the conodonts:

Gastropoda
Ophileta sp.
Murchisonia simulatrix Billings

Trilobita
Bathyuriscus timon Billings—probably *Jeffersonia angustimarginata* sp. nov.
Petigurus nero (Billings)
Illaenus fraternus Billings—possibly misidentified *Benthamaspis hintzei* sp. nov. and/or *Randaynia langdoni* sp. nov.

In 1985, the exact stratigraphic positions of Barnes and Tuke's (1970) conodont samples A and B were identified (see

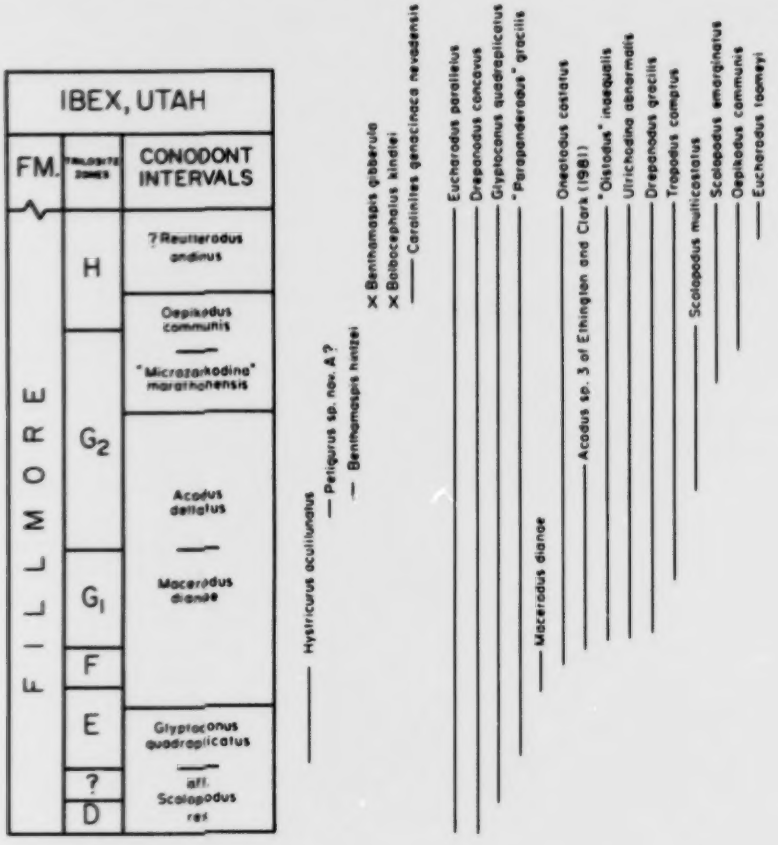


Figure 5. *Ranges of Ibexian trilobite and conodont species common to western Newfoundland. Trilobite data from Hintze (1953), Terrell (1973) and Young (1973); conodont data from Ethington and Clark (1981).*

Figure 3). The samples were originally collected from grainstones between algal mounds (R.K. Stevens, personal communication, 1985) and the geographic location of each was visited to find the appropriate unit. Both sampled localities were found to definitely occur above the Boat Harbour 'pebble bed' of Knight (1977b, 1978, 1980b), and Boyce (1978, 1983b). Furthermore, it was determined that both samples were obtained from the same bed, although they were taken 1 km apart (see Figure 3) and Barnes and Tuke (1970, Table 1) documented slightly differing species assemblages.

The samples were obtained from Bed 25 of Section BHS-6 of the Boat Harbour composite section. The bed is distinctive. It is about 1.6-m thick and consists of algal mounds having highly fossiliferous grainstones between them. The base of the bed occurs 3.16 m above the top of the 'pebble bed'. The mounds are large, isolated, steep-sided, circular to slightly elliptical, and up to 1.5 m in diameter (Boyce, 1983b; see Appendix 1). The Ross–Hintze Zone G_2 trilobite *Benthamaspis hintzei* first appears in this bed.

Twenty-one conodont species were obtained by Barnes and Tuke (1970, Table 1). Of these, ten form an assemblage that is also recognizable in the Pogonip Group at Ibex, Utah (Ethington and Clark, 1981). The species and their Ross–Hintze zonal ranges are as follows:

?Acodus sp. 3 of Ethington & Clark (1981)	–Zone F to Zone G_2
Drepanodus concavus (Branson & Mehl)	–Zone D to Zone J
Eucharodus parallelus (Branson & Mehl)	–Zone B to Zone L
Oistodus inaequalis Pander s.f.	–Zone G_1 to Zone J
Oneotodus costatus Ethington & Brand	–Zone E to Zone I
'Scolopodus' emarginatus Barnes & Tuke	–Zone G_2 to Zone I
'Parapanderodus' gracilis (Ethington & Clark)	–Zone E to Zone M
Scolopodus multicostatus Barnes & Tuke	–Zone G_2
Glyptoconus quadraplicatus (Branson & Mehl) s.f.	–Zone D to Zone I
Ulrichodina abnormalis (Branson & Mehl)	–Zone G_1 to Zone I

With reference to Ethington and Clark (1981, Figure 3), the above species assemblage is firmly indicative of an early Arenig Ross–Hintze Zone G_2 age. The biostratigraphic conclusion of Boyce (1979a,b, 1983a,b) and Stouge (1982) as to the age of the Boat Harbour Formation above the 'pebble bed' is thus supported by the data of Barnes and Tuke (1970).

Bolbocephalus kindlei sp. nov. occurs in the *Strigigenalis caudata* Zone at Cape Norman. At Eddies Cove West, it is associated with *Benthamaspis gibberula* (Billings) in beds of the *Strigigenalis caudata* Zone. In the Ibexian sequence, *Bolbocephalus kindlei* occurs in the lower half of Zone H associated with *Benthamaspis gibberula* (Billings) and *Carolinites genacinaca nevadensis* Hintze.

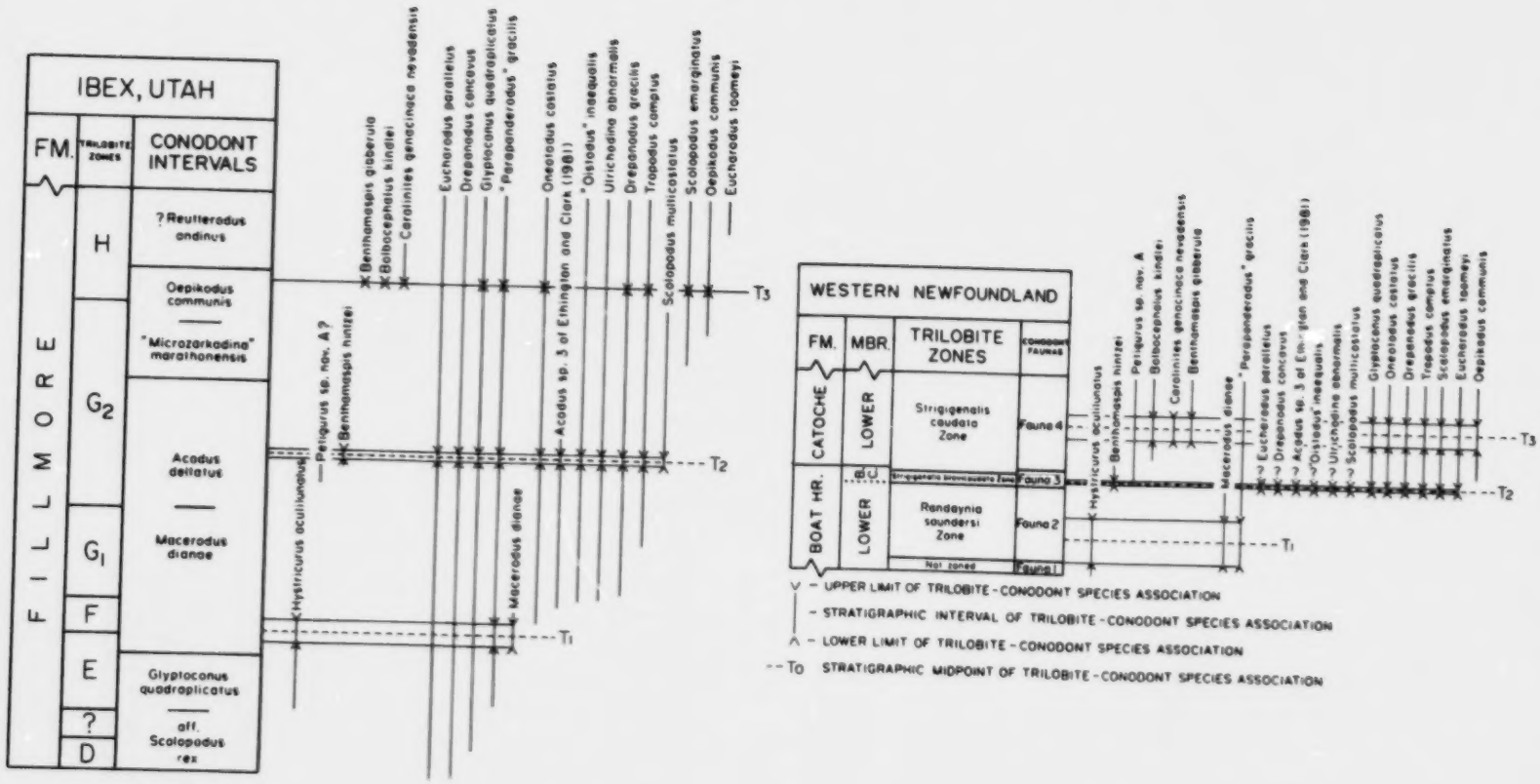


Figure 6. *Range comparison and correlation of trilobite–conodont associations common to Ibex, Utah and western Newfoundland. Ibexian trilobite data from Hintze (1953), Terrell (1973) and Young (1973); conodont data from Ethington and Clark (1981). Western Newfoundland trilobite data from Fortey (1979a), Boyce (1979a,b, 1983a,b, 1985, 1986,* this study), *Boyce* in *Stouge and Boyce (1983) and Williams* et al. *(1987); conodont data from Barnes and Tuke (1970), Stouge (1982) and Stouge* in *Stouge and Boyce (1983). B.C. = Barbace Cove.*

Benthamaspis gibberula (Billings) and *Carolinites genacinaca nevadensis* Hintze occur together in the upper part of the *Strigigenalis caudata* Zone of the Port au Choix Peninsula (Fortey, 1979a, Figure 11; Boyce, 1985, Figure 2; Williams *et al.*, 1987, Figure 2). Fortey (1979a, page 64) has already pointed out that these species occur together in the lower half of Ibexian Zone H. The associated conodont species *Glyptoconus quadraplicatus* (Branson and Mehl), *Oneotodus costatus* Ethington and Brand, *'Parapanderodus' gracilis* (Ethington and Clark), *Drepanodus? gracilis* (Branson and Mehl), *Tropodus comptus* (Branson and Mehl), *Eucharodus toomeyi* (Ethington and Clark) and *Oepikodus communis* (Ethington and Clark) support this correlation. The upper part of the *Strigigenalis caudata* Zone may extend into Ibexian Zone I based on cephalopod and trilobite data (Flower, 1978, Figure 43.2; Boyce, 1986; Williams *et al.*, 1987).

In summary, the *Randaynia saundersi* Zone probably correlates with the latter part of Zone E to latest Zone F. The *Strigigenalis brevicaudata* Zone lies entirely within Zone G_2. The base of the *Strigigenalis caudata* Zone occurs within Zone G_2, whilst the top of the zone may extend into Zone I. These conclusions are in accord with those of Boyce (1979a,b, 1983a,b), Fortey (1979a) and Stouge (1982). The Ibex, Utah–western Newfoundland correlations are summarized in Figure 7, which also shows the relationship of Stouge's (1982) conodont faunas and Flower's (1978) cephalopod zones to the trilobite zones proposed here.

[The magnitude of the hiatus marked by the 'pebble bed' was determined in the following way. The intervals marked by T_1 and T_2 in Figure 6 were assumed to represent the same period of time because they contain identical trilobite–conodont species associations. The distance from T_1 to the 'pebble bed' was measured on the western Newfoundland column then converted to the proportional distance on the Ibex, Utah column. The same procedure was followed for the distance from T_2 to the 'pebble bed'.]

Boyce (1978) correlated the *Randaynia saundersi* Zone beds with Ibexian zones B to D; the *Strigigenalis brevicaudata* and *Strigigenalis caudata* Zone beds were correlated with Zone G. These correlations were tentative, based on sparse, poorly preserved trilobite material, and are now considered to be erroneous.

Flower's (1978, Figure 43.2) correlations differ from those described here. He correlated the beds of the *Randaynia saundersi* Zone with Ibexian Zone D (in part) to Zone E (his *Basslerocerας–Lecanospira* Zone IV). The beds of the *Strigigenalis brevicaudata* Zone (his *Pycnoceras apertum* Zone VI), he correlated with Ibexian Zone G_1. The beds of the *Strigigenalis caudata* Zone (his *Cassinoceras wortheni* Zone VIII) were correlated with Ibexian Zone 1. Flower's (1978) correlations were based on the generic similarities of the compared cephalopod and gastropod faunas.

CORRELATIONS WITH THE STANDARD CANADIAN SERIES DEPOSITS

The Canadian Series was formally introduced by Dana (1874, page 214) for the fossiliferous deposits of the Levis Formation exposed at Lévis, Quebec (Fahraeus, 1977b, page 982). However, at present, the Beekmantown Group of New York–Vermont and laterally equivalent deposits in Missouri–northern Arkansas are commonly utilized as the standard deposits of the Canadian Series (Flower, 1964; Whittington, 1968; Fahraeus, 1977b). Flower (1964, pages 17-19) treated the Canadian Series as a system and proposed four stages: *Gasconadian*–from Missouri–northern Arkansas, *Demingian* (= *Roubidouxian* of Fisher, 1982)–from New Mexico and New York, *Jeffersonian*–from Missouri–northern Arkansas and *Cassinian*–from New York. The purpose of this part of the study is to correlate the trilobite faunas of the Boat Harbour and Catoche formations with those of the Canadian deposits of New York–Vermont and Missouri–northern Arkansas.

The trilobite species common to New York–Vermont, Missouri–northern Arkansas and western Newfoundland are listed in Table 4, and Figure 8 shows the range comparison and correlation of the trilobite species associations common to the three areas. The correlations are discussed further in the text.

New York–Vermont

The *Randaynia saundersi* Zone trilobites *Hystricurus oculilunatus* Ross and *Paraplethopeltis seelyi* (Whitfield) also occur in the standard deposits of the Demingian Stage, the Fort Ann and lower Bascom formations of Fisher and Mazzullo (1976) and Mazzullo and Friedman (1975, 1977).

The trilobites Gen. et sp. ind. Whittington (1953, page 670; Plate 68, figures 30-32) and *Nileus striatus* Whitfield (1897, page 184; Plate 5, figures 5, 6) occur in the standard deposits of the Cassinian Stage, the Fort Cassin and upper Bascom formations of Fisher and Mazzullo (1976) and Mazzullo and Friedman (1975, 1977). Fortey (1979a) correctly synonymized these species with the *Strigigenalis caudata* Zone trilobites *Strigigenalis caudata* (Billings) and *Benthamaspis gibberula* (Billings), respectively.

Missouri–northern Arkansas

The *Randaynia saundersi* Zone trilobite *Hystricurus deflectus* Heller (1954, pages 43-44; Plate XVIII, figures 6-8) also occurs in the standard deposits of the Demingian Stage *sensu* Flower (1964) (= Roubidouxian, Fisher, 1982), the Roubidoux Formation of Nason (1892).

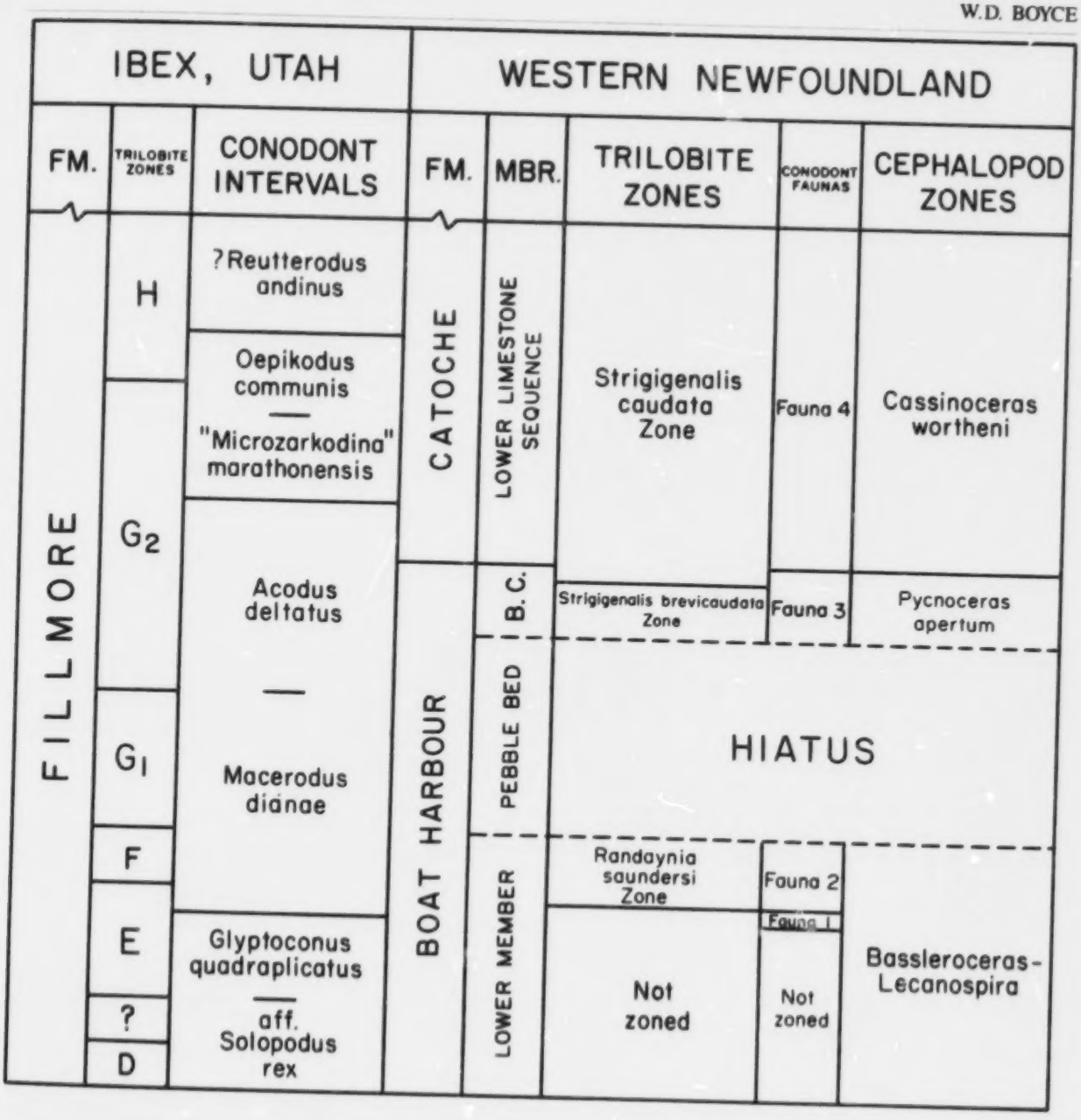


Figure 7. *Correlation of western Newfoundland trilobite zones, conodont faunas and cephalopod zones with the standard trilobite zones and conodont intervals of Ibex, Utah. B.C. = Barbace Cove.*

Genus(?) sp.(?) Cullison (1944, pages 84-85; Plate XXXV, figures 23, 24) occurs in the standard deposits of the lower part of the Jeffersonian Stage *sensu* Flower (1964), and the Theodosia Formation of the Jefferson City Group (Cullison, 1944). This species, on morphological grounds, is considered to be synonymous with *Petigurus* sp. nov. A. *Petigurus* sp. nov. A first appears in beds of the *Strigigenalis brevicaudata* Zone at Eddies Cove West and at Barbace Point, Port au Choix Peninsula. It ranges into the upper part of the *Strigigenalis caudata* Zone. In the Eddies Cove West and Port au Choix *Strigigenalis brevicaudata* beds, this species is associated with *Peltabellia crassimarginata* (Cullison, 1944) which also occurs in the late Jeffersonian Theodosia Formation.

Table 4. Canadian Series trilobite species common to western Newfoundland.

TRILOBITE SPECIES	OCCURRENCES IN CANADIAN SERIES DEPOSITS				WESTERN NEWFOUNDLAND
	NEW YORK – VERMONT		MISSOURI – NORTHERN ARKANSAS		
	STAGE	FORMATION	STAGE	FORMATION	ZONAL RANGE
Hystricurus oculilunatus	Demingian	Fort Ann			*Randaynia saundersi* Zone
Hystricurus deflectus			Demingian	Roubidoux	*Randaynia saundersi* Zone
Paraplethopeltis seelyi	Demingian	Fort Ann			*Randaynia saundersi* Zone
Peltabellia crassimarginata			Jeffersonian	Theodosia	*Strigigenalis brevicaudata* Zone
Petigurus sp. nov. A (=*Petigurus* sp. indet of Fortey, 1979a)			Jeffersonian	Theodosia	*Strigigenalis brevicaudata* Zone to *Strigigenalis caudata* Zone*
Strigigenalis caudata	Cassinian	Fort Cassin	Cassinian	Cotter	*Strigigenalis caudata* Zone
Benthamaspis gibberula	Cassinian	Fort Cassin			*Strigigenalis caudata* Zone*

* range applies to Eddies Cove West and Port au Choix areas.

Note: Canadian Series trilobite data from Cullison (1944), Flower (1968c), Heller (1954), Whitfield (1889a, 1897) and Whittington (1953). Western Newfoundland trilobite data from Boyce (1979a,b, 1983a,b, 1985, 1986, *this study*), Fortey (1979a), Boyce *in* Stouge and Boyce (1983) and Williams *et al.* (1987).

Goniotelus semicircularis Cullison (1944, page 84; Plate XXXV, figures 25, 26) is synonymized with the nominate species of the *Strigigenalis caudata* Zone *(this study)*. This species occurs in the Cotter Formation, which was assigned by Flower (1964, page 19) to the uppermost part of the Jeffersonian Stage.

If the synonymy of the Cassinian Gen. et sp. indet. Whittington and the Jeffersonian *Goniotelus semicircularis* Cullison as proposed by Fortey (1979a) and this study is correct, the Cotter Formation is probably better referred to the lowermost part of the Cassinian Stage rather than the uppermost part of the Jeffersonian Stage. This is in agreement with Flower (1978, page 220, Figure 43.2) who reassigned the Cotter Formation to the lowermost part of the Cassinian.

Summary

The *Randaynia saundersi* Zone is Demingian, the *Strigigenalis brevicaudata* Zone is late Jeffersonian, and the *Strigigenalis caudata* Zone is Cassinian. This information is summarized in Figure 9.

Ross *et al.* (1982) abandoned Flower's (1957, 1964) Canadian stages. However, they are useful and are easily applicable in Newfoundland; hence it is recommended that they be retained, despite the fact that their boundaries have not been formally defined. For example, the base of the Cassinian Stage can be defined by the first occurrence of *Strigigenalis caudata* (Billings), which occurs in Newfoundland, the Mingan Islands, New York–Vermont, Pennsylvania and Missouri–northern Arkansas.

CORRELATION OF THE CANADIAN SERIES WITH THE IBEXIAN TRILOBITE ZONATION

Correlations of the Canadian Series trilobite faunas with the Ibexian trilobite zonation of Ross (1951) and Hintze (1953), have been hampered because of the apparent low diversity and paucity of up-to-date systematic studies of the Canadian trilobite faunas. Also, common species have been masked under different names.

The trilobite species common to the Canadian and Ibexian series are listed in Table 5. The actual correlations of the ranges of these species are shown in Figure 10. The correlation of the stages of the Canadian Series with the trilobite zones and conodont intervals of the Ibexian Series is summarized in Figure 11.

The common occurrence of *Hystricurus oculilunatus* Ross suggests that the Demingian Stage is partly equivalent to Ibexian zones E and F. This agrees with Flower (1964, 1978, page 220; Figure 43.2).

Petigurus sp. nov. A., the Jeffersonian Genus(?) sp.(?) Cullison (1944, pages 84-85; Plate XXXV, figures 23, 24) and the undetermined pygidium illustrated by Hintze (1953; Plate XX, figure 14) from Zone G_2 are considered to be tentatively synonymous. If this is so, it would suggest that the Jeffersonian Stage is partly equivalent to Ibexian Zone G_2; this is in accord with Flower (1978, page 220; Figure 43.2).

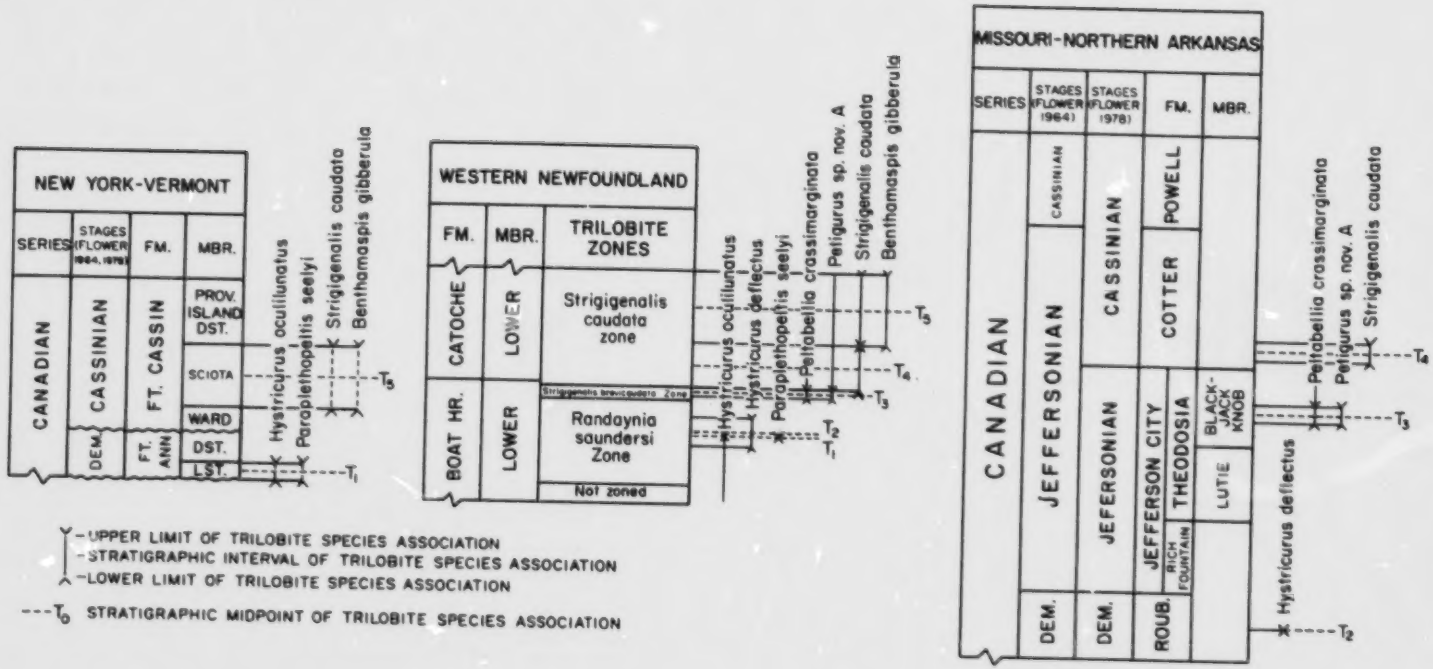


Figure 8. *Range comparison and correlation of trilobite species associations common to New York – Vermont, Missouri – northern Arkansas and western Newfoundland. New York – Vermont data from Flower (1968c), Whitfield (1889a, 1897) and Whittington (1953); Missouri – northern Arkansas data from Cullison (1944) and Heller (1954); western Newfoundland data from Boyce (1983a,b, 1985, 1986,* this study), *Boyce* in *Stouge and Boyce (1983), Fortey, (1979a) and Williams* et al. *(1987). DEM. = Demingian, B. C. = Barbace Cove, ROUB. = Roubidoux.*

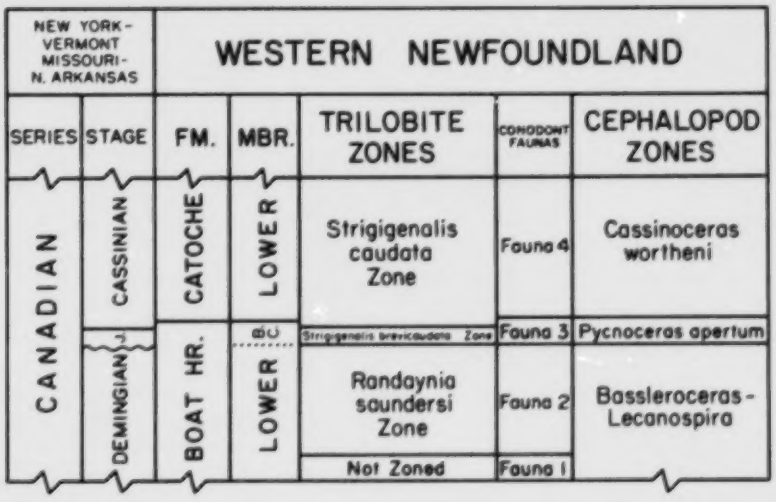


Figure 9. *Correlation of western Newfoundland trilobite zones, conodont faunas and cephalopod zones with the stages of the Canadian Series. J. = Jeffersonian, B.C. = Barbace Cove.*

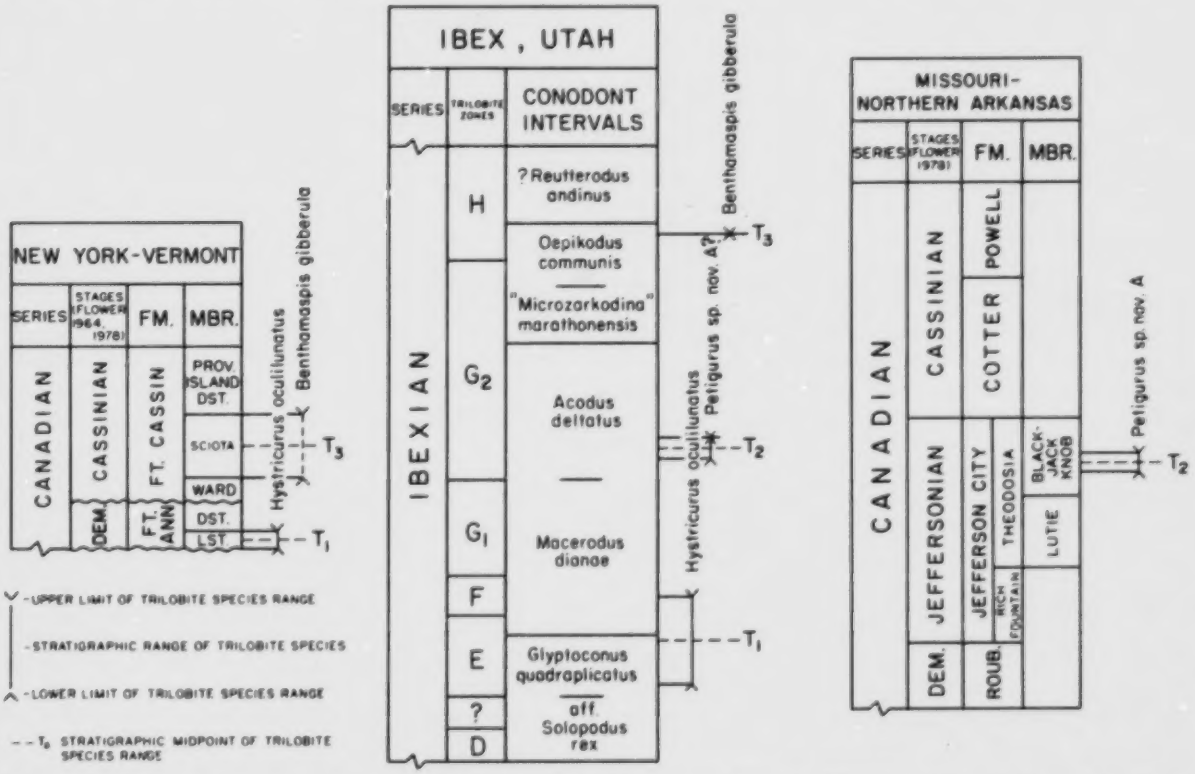


Figure 10. *Range correlations of trilobite species common to New York–Vermont, Missouri–northern Arkansas and Ibex, Utah. New York–Vermont data from Flower (1968c), Whitfield (1889a, 1897); Missouri–northern Arkansas data from Cullison (1944); Ibex, Utah data from Hintze (1953), Terrell (1973) and Young (1973). DEM. = Demingian, ROUB. = Roubidoux.*

Table 5. Trilobite species common to Canadian and Ibexian series.

TRILOBITE SPECIES	OCCURRENCE IN CANADIAN SERIES	OCCURRENCE IN IBEXIAN SERIES
Hystricurus oculilunatus	Demingian Stage	Zone E to Zone F
Petigurus sp. nov. A	Jeffersonian Stage	Zone G_2?
Benthamaspis gibberula	Cassinian Stage	Zone H

Note: Canadian Series trilobite data from Cullison (1944), Flower (1968c) and Whitfield (1889a, 1897). Ibexian Series trilobite data from Hintze (1953), Terrell (1973) and Young (1973).

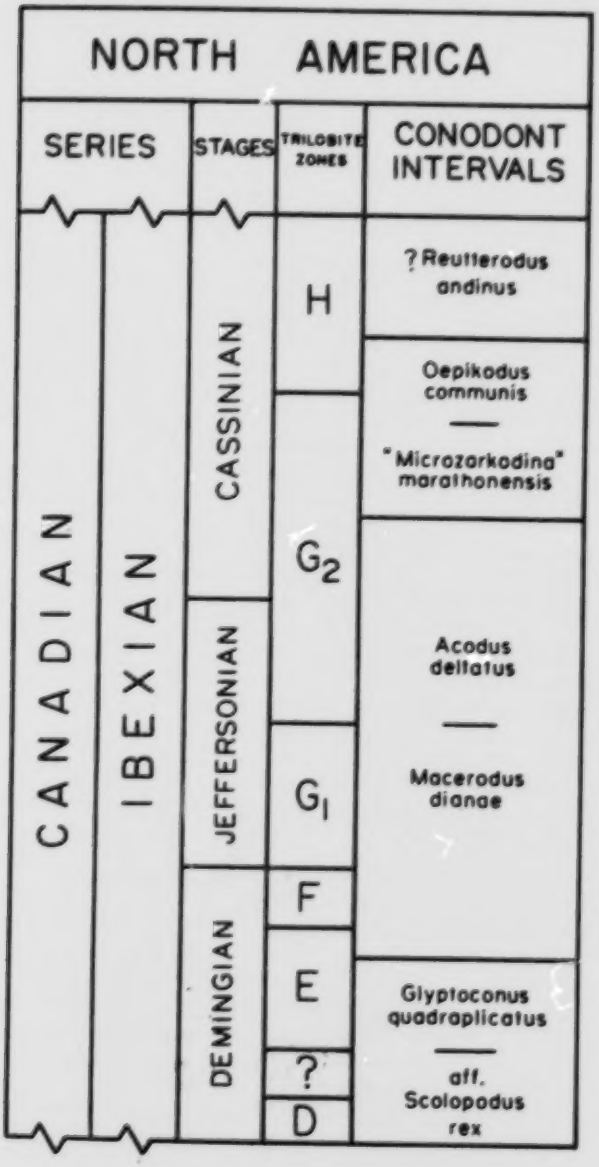


Figure 11. *Correlation of stages of the Canadian Series with trilobite zones and conodont intervals of the Ibexian Series.*

The synonymy of the Cassinian species *Nileus striatus* Whitfield, and the Zone H species *Benthamaspis distinctus* Young with *Benthamaspis gibberula* (Billings) (Fortey, 1979a, page 100) suggests that the Cassinian Stage is partly equivalent to Ibexian Zone H. This is also in agreement with Flower (1978, page 220; Figure 43.2).

SYSTEMATIC PALEONTOLOGY

ASSOCIATION OF TRILOBITE PARTS

Guidelines for the association of separate pieces of individual trilobite species have been outlined previously by Fortey (1979a, page 63).

In general, the association of librigenae with cranidia is simple, and is accomplished merely by comparing their size, convexity, prosopon (surface ornamentation) and the fit of their facial sutures. However, the association of pygidia and hypostomata with cranidia is more difficult. The problem can be obviated if, 1) a complete or nearly complete specimen is obtained, or, 2) the remains of a single species or several highly distinct species are concentrated in one horizon. Furthermore, pygidia and hypostomata often have the same type of prosopon and display similar degrees of effacement and/or convexity as their associated cranidia. In particular, the glabella and the pygidial axis often have the same prosopon type.

TERMINOLOGY

The terminology used in this taxonomic study is that of Moore (1959), with additional terms from Öpik (1967), Richter and Richter (1949) and Whittington (1965). The glabella includes the occipital ring, except when the term preoccipital glabella is used.

REPOSITORIES OF ILLUSTRATED MATERIAL

The specimens illustrated in this study are housed in the following institutions:

AMNH —American Museum of Natural History, New York, New York, U.S.A.
MMH —Geologisk Museum, University of Copenhagen, Copenhagen, Denmark.
GSC —Geological Survey of Canada, Ottawa, Ontario, Canada.
NFM —Newfoundland Museum, St. John's, Newfoundland, Canada.
UMo —University of Missouri, Columbia, Missouri, U.S.A.
USNM —United States National Museum, Smithsonian Institution, Washington, D.C., U.S.A.
YPM —Yale Peabody Museum, New Haven, Connecticut, U.S.A.

SYSTEMATIC DESCRIPTIONS

The classification followed in this report, is essentially that of Moore (1959), except that Hupé's (1953) concept of the Bathyuridae is used, and the Order Proetida of Fortey and Owens (1975) is recognized. Many of the taxa described herein are new but have been referred to in earlier publications under different names (Boyce, 1978, 1979a,b, 1983a, 1986). Although the species were not illustrated, the differing names have been included in the synonymies because they refer to the *same material* this study is based on.

Order PTYCHOPARIIDA Swinnerton, 1915
Superfamily LEIOSTEGIACEA Bradley, 1925
Family LEOISTEGIIDAE Bradley, 1925
Subfamily LEIOSTEGIINAE Bradley, 1925
Genus *Leiostegium* Raymond, 1913

Type species. Bathyurus quadratus Billings, 1860 from the Levis Formation at Point Levis, Quebec.

Diagnosis. Glabella straight-, parallel-sided, quadrate, subrectangular to gently tapering. Pygidium subtriangular, semicircular to parabolic; axis narrower than pleural fields; posterior border narrow to wide, convex.

Remarks. For some time now, there has been a debate as to whether *Leiostegium* Raymond, 1913 is more properly a subgenus of *Lloydia* Vogdes, 1890 or vice versa (Berg and Ross, 1959; Lochman, 1964, 1965; Shaw, 1966; Flower, 1968a). Ross (1970, page 73) pointed out, 1) the type specimen of *Lloydia* Vodges is a cranidium of *Bathyurus bituberculatus* Billings (1865, page 410, figure 391), characterized by discrete oblong preoccipital glabellar lobes, and 2) no pygidium had ever been described for this species. Ross (1970, page 74) further recommends that *Lloydia* be restricted to species having preoccipital glabellar lobes as in *L. bituberculatus*. *Leiostegium proprium* sp. nov. (below) conforms in most respects to the generic definition of *Leiostegium*. However, the cranidium exhibits a weakly defined pair of oblong preoccipital lobes. If one follows Ross' (1970) recommendation that the genus *Lloydia* be restricted to species having preoccipital glabellar lobes, then it is obvious that *L. proprium* could have just as easily been assigned to *Lloydia* as *Leiostegium*. For this reason, it is probable that *Leiostegium* will eventually prove to be a subgenus of *Lloydia*. However, until a pygidium is assigned to *L. bituberculatus* the two are regarded as separate genera, and, following Ross (1970, page 74), *Lloydia* is regarded as being monotypic.

Leiostegium proprium sp. nov.
Plate 2, figures 1-9

1978 *Lloydia* sp. Boyce, page 83.
1978 *Lloydia (Leiostegium)* sp. Boyce, page 83.
1979b *Lloydia* sp. nov. Boyce.
1983a *Lloydia* sp. nov. Boyce, page 11.
1983 *Leiostegium* sp. nov. Boyce, *in* Stouge and Boyce; Plate 16, figures 1 and 2.

Diagnosis. Glabella strongly convex, with weakly defined pair of preoccipital glabellar lobes. Pygidial axial lobe cylindro-conical; at least seven distinct axial rings. Posterior border strongly defined. Prosopon of dense punctae.

Etymology. From the Latin *proprium*, distinctive, referring to the nature of the prosopon.

Stratigraphic range. Lower member of the Boat Harbour Formation, Unit 9 of Pratt's (1979) Eddies Cove West section.

Material. Six (6) cranidia; ten (10) pygidia.

Holotype. Cranidium, NFM F-110, from Unit 9 of Pratt's (1979) section in the Lower member of the Boat Harbour Formation at Eddies Cove West, western Newfoundland (here designated).

Paratype. Pygidium, NFM F-111 from the same horizon as the holotype (here designated).

Description. Glabella highly convex, transversely strongly vaulted, straight- and parallel-sided, anteriorly broadly rounded; it extends total cranidial length. Occipital ring sagittally narrow, subrectangular. Weakly defined pair of oblong preoccipital glabellar lobes. Preglabellar and axial furrows well defined, narrow, deep; occipital furrow slightly less so. Preglabellar field not developed. Anterior border and anterior border furrow not preserved. Anterior fixigenal areas wide, convex, anteriorly steeply downsloping. Palpebral fixigenal areas only slightly wider than anterior fixigenal areas, abaxially horizontal to very gently downsloping, exsagittally anteriorly steeply downsloping. Palpebral lobes relatively short, exsagittal length about one-quarter sagittal glabellar length, wide. Palpebral furrow indistinct, narrow, shallow. Line through centres of palpebral lobes crosses glabellar sagittal line at about one-half glabellar length from posterior edge of occipital ring. Posterior fixigenal areas wide, weakly convex, posteriorly horizontal to weakly downsloping. Posterior border furrow well defined, wide, deep. Prosopon of dense punctae.

Hypostoma, librigenae and thorax unknown.

Pygidium moderately convex, oblong; length about three-fifths maximum width (estimated) at posterior end of articulating facets. Axial lobe cylindro-conical, transversely strongly arched, posteriorly gently tapering and abruptly rounded, highly convex; it extends about six-sevenths to nine-tenths total pygidial length. At least seven axial rings (excluding terminal ring) of posteriorly decreasing sagittal width. Axial furrows distinct, narrow, deep. Pleural and interpleural furrows not developed. Posterior border strongly defined, narrow, weakly convex. Posterior border furrow distinct, narrow, deep. Prosopon of dense punctae.

Remarks. The only other known species of *Leiostegium* with a punctate prosopon is *Leiostegium (Alloleiostegium) punctatum* Zhou and Zhang (1978, pages 13, 24-25; Plate II,

figures 1-8) from basal Ordovician rocks of the Tangshan area, China. The clearly defined lateral glabellar furrows, the presence of three pairs of pleural furrows on the pygidium and the absence of a pygidial posterior border and posterior border furrow however, readily distinguishes this species from *L. proprium*.

Superfamily ASAPHACEA Burmeister, 1843
Family ASAPHIDAE Burmeister, 1843
Subfamily ISOTELINAE Angelin, 1854
Genus *Isoteloides* Raymond, 1910

Type species. Asaphus canalis Whitfield, 1886 from the Fort Cassin Formation at Fort Cassin, Champlain Valley, New York.

Diagnosis. See Jaanusson *in* Moore (1959, page O341).

Isoteloides peri Fortey, 1979a
Plate 3, figures 1-8

1958 *Isoteloides* cf. *I. flexus* Hintze; Sando, pages 842, 854; Plate 2, figures 33-35.
1967 *Isoteloides* sp. Lees, pages 27, 39, 78-79; Plate 12, figures 1-3, 9.
1978 *Isoteloides* sp. Boyce, page 83.
1979a *Isoteloides peri* sp. nov. Fortey, pages 69-72; Plate 23, figures 1-8.
1979b *Isoteloides* sp. nov. Boyce.
1983 *Isoteloides peri* Fortey; Boyce *in* Stouge and Boyce; Plate 14, figure 8; Plate 15, figures 2, 5.
1983b *Isoteloides peri* Fortey; Boyce, pages 81-82; Plate 2, figures 5-8.

Diagnosis. Anterior sections of facial sutures slightly divergent. Eyes small. Pygidium about two-thirds as long as wide, distinct border of moderate width. Diagnosis from Fortey (1979a, page 69).

Stratigraphic range. Barbace Cove Member of the Boat Harbour Formation and lower limestone sequence of the Catoche Formation, 80.37 to 93.60 m above the base of the Boat Harbour composite section.

Material. Sixteen (16) cranidia; twelve (12) hypostomata; twenty-two (22) librigenae; forty-one (41) pygidia.

Holotype. Cranidium, GSC 56799, from the Catoche Formation on Port au Choix Peninsula, western Newfoundland (Fortey, 1979a—by monotypy).

Paratypes. Cranidium, GSC 56800; hypostoma, GSC 56805; librigena, GSC 56804; pygidia, GSC 56801, GSC 56802, GSC 56803; all from the Catoche Formation on Port au Choix Peninsula, western Newfoundland (Fortey, 1979a by monotypy).

Remarks. As Fortey (1979a) has already provided a detailed description of *I. peri*, it is not repeated here.

Sando (1958, pages 842, 854; Plate 2, figures 33-35) illustrated *Isoteloides* cf. *I. flexus* Hintze from the Rockdale Run Formation near Chambersburg, Pennsylvania. According to Fortey (1979b, page 38) this species is probably identical to *I. peri*. A comparison of the photographs of the two species suggests that Fortey is correct in his assignment. Accordingly, the *Isoteloides* species from Pennsylvania is synonymized with *I. peri*.

Isoteloides latimarginatus Fortey, 1979a
Not figured

1979a *Isoteloides latimarginatus* sp. nov. Fortey, pages 72-73; Plate 24, figures 1-9.

Diagnosis. Isoteloides with wide, flat pygidial border. Palpebral lobes of medium size. Hypostoma more deeply forked than other species of the genus. Diagnosis from Fortey (1979a, page 72).

Stratigraphic range. Lower limestone sequence of the Catoche Formation, 15.81 to 15.97 m above the base of the Cape Norman section.

Material. One (1) pygidium.

Holotype. Pygidium, GSC 56806, from the Catoche Formation on Port au Choix Peninsula, western Newfoundland (Fortey, 1979a—by monotypy).

Paratypes. Cranidia, GSC 56807, GSC 56808; hypostoma, GSC 56813; librigenae, GSC 56810, GSC 56812; pygidia, GSC 56809, GSC 56811; all from the Catoche Formation on Port au Choix Peninsula, western Newfoundland (Fortey, 1979a—by monotypy).

Remarks. As Fortey (1979a) has already provided a detailed description of *I. latimarginatus*, it is not repeated here.

Superfamily ILLAENACEA Hawle and Corda, 1847
Family ILLAENIDAE Hawle and Corda, 1847
Subfamily ILLAENINAE Hawle and Corda, 1847
Genus *Illaenus* Dalman, 1827

Type species. Entomostracites crassicauda Wahlenberg, 1821.

Diagnosis. See Lochman-Balk *in* Moore (1959, page O372)

Illaenus sp. nov.
Not figured

1986 *Illaenus* sp. nov. Boyce, pages 162, 166

Stratigraphic range. Lower limestone sequence of the Catoche Formation, 1.34 to 17.39 m above the base of the Cape Norman section.

Material. Five (5) cranidia; one (1) librigena; three (3) pygidia.

Remarks. The small amount of generally poorly preserved material, collected from Cape Norman, precludes the formal naming of this new species. However, abundant additional material has been collected from Forked Feeder Pond (near Hawkes Bay), Schooner Island and Burnt Island in Pistolet Bay, and the road to Roddickton (Boyce, 1986; Boyce *et al.*, 1988). This additional material, when it is studied and described in detail, will allow the formal naming of the species.

Order PROETIDA Fortey and Owens, 1975
Subfamily HYSTRICURINAE Hupé, 1953
Genus *Hillyardina* Ross, 1951

1951 *Hyperbolochilus* Ross, page 77.
1985 *Tanybregma* Jell and Stait, pages 8-9.

Type species. Hillyardina semicylindrica Ross, 1951, from the Garden City Formation of northeastern Utah.

Diagnosis. Glabella straight- to convex-sided, anteriorly tapering and abruptly rounded to pointed. Occipital ring well defined, subtriangular to subrectangular. Preglabellar field wide, anteriorly steeply downsloping; median preglabellar furrow variably developed. Anterior border wide and of constant width, flat to strongly concave. Palpebral lobes generally small, plate-like. Palpebral furrow generally indistinct, concave-outward. Anterior portions of facial suture slightly to strongly divergent; posterior portions strongly divergent. Posterior fixigenal areas acutely triangular. Cranidial prosopon pustulose to smooth. Genal field of librigena highly convex. Lateral border wide, flat to strongly concave, abaxially gently tapering. Thorax with nine narrow thoracic segments of equal length; long, narrow, curved dorsal axial spine on fourth or fifth segment. Pygidium small, semielliptical to triangular. Axial lobe straight- to concave-sided, posteriorly strongly tapering and abruptly rounded to pointed or truncated, composed of 3 to 5 axial rings. Pleural and interpleural furrows well developed, 3 or 4 pairs. Posterior border posteriorly steeply downsloping to vertical, flat to weakly convex.

Remarks. The closely similar genera *Hillyardina* and *Hyperbolochilus* were originally described by Ross (1951) from Zone F in northern Utah. *Hyperbolochilus* was differentiated from *Hillyardina* by the more strongly divergent anterior portions of the facial suture, lack of a median preglabellar furrow, shape of the glabella, position of posterior border furrow, lack of pustules and the lack of a boss within the genal angle (Ross, 1951, page 77). They were particularly differentiated, *generically*, by the presence of the raised boss within the genal angle on *Hillyardina* and by the more strongly divergent anterior portions of the facial suture of *Hyperbolochilus*. Hintze (1953) and Terrell (1973) suggested that these differences are of specific rather than generic value, thereby implying that the two genera are congeneric. Hintze (1953, pages 162-163; Plate VIII, figures 5, 6) and Terrell (1973, pages 71-73; Plate 3, figures 1-5) described *Hillyardina* sp. A.

Hillyardina minuspustulata sp. nov. exhibits the median preglabellar furrow characteristic of *Hillyardina*. The cranidial prosopon is transitional between *Hillyardina* and *Hyperbolochilus*—the glabella exhibits the pustulose prosopon of *Hillyardina* whilst the rest of the cranidium is smooth like *Hyperbolochilus*. The boss within the genal angle (characteristic of *Hillyardina)* is variably developed. *Hillyardina levis* sp. nov. also variably displays this boss, although the rest of its features are typical of *Hyperbolochilus*.

Ross (1951), Hintze (1953) and Terrell (1973) were not able to assign pygidia to either *Hillyardina* or *Hyperbolochilus*. *Hillyardina minuspustulata* and *H. levis* belong to *Hillyardina* and *Hyperbolochilus sensu* Ross (1951), respectively. Their pygidia are clearly congeneric (compare Plate 5, figures 6-9 and Plate 7, figures 6-10). On this basis and the previously mentioned intergradational nature of the morphological characters, *Hillyardina semicylindrica* Ross and *Hyperbolochilus marginauctum* Ross are regarded as two different species of the same genus. Since Ross (1951) defined *Hillyardina* first in his study, *Hyperbolochilus* is considered to be a junior subjective synonym of that genus.

Besides the species discussed above, the following species are assigned to *Hillyardina* Ross, 1951: *Jeffersonia bridgei* Heller (1954, pages 46-47; Plate XVIII, figures 16,17), *Hyperbolochilus expansus* Kobayashi (1955, pages 422-424; Plate III, figure 1), *Hyperbolochilus?* sp. nov. of Fortey, (1983, pages 193-195; Plate 25, figures 10,11), *Hystricurus lewisi* (Kobayashi, 1940) of Jell and Stait (1985, pages 5-8; Plate 2, figures 1-4, 15 only; Plate 3, figures 9,10,13), *Tanybregma tasmaniensis* Jell and Stait (1985, pages 8-9; Plate 3, figures 1-7; Plate 8, figure 7) and *Hystricurus* sp. cf. *H. robustus* Ross of Jell and Stait (1985, page 8; Plate 3, figures 8, 11 only).

Despite its large palpebral lobes, *Tanybregma tasmaniensis* Jell and Stait (1985, pages 8-9; Plate 3, figures 1-7; Plate 8, figure 7) can be comfortably accommodated within the revised concept of *Hillyardina*. *Tanyoregma tasmaniensis* has the concave anterior border, large preglabellar area, widely divergent anterior facial sutures, weak 1P lateral glabellar furrows and long posterior fixigenal areas found in *Hillyardina;* its free cheek also displays the typical wide, concave lateral border and long genal spine of *Hillyardina*. No pygidium was attributed to *T. tasmaniensis* by Jell and Stait (1985). However, a likely candidate is the pygidium they identified as *Hystricurus* sp. cf. *H. robustus* Ross (Jell and Stait, 1985; Plate 3, figure 11). The prosopon of tubercules on the pygidial axis matches the glabellar prosopon of *T. tasmaniensis* (Jell and Stait, 1985; Plate 3, figures 2, 3, and 7). This pygidium easily fits within the concept of *Hillyardina*.

The large palpebral lobes of *T. tasmaniensis* are considered to be of specific rather than generic significance. Furthermore, until vastly different pygidia are definitely assigned to *T. tasmaniensis*, on the basis of the previously mentioned morphological similarities, *Tanybregma* Jell and Stait, 1985 is regarded as a junior subjective synonym of *Hillyardina* Ross, 1951.

Omuliovia mira Chugaeva, 1962 has strongly developed lateral 1P glabellar furrows (see Chugaeva, 1973 pages 73-76; Plate V, figures 1-3; Plate VI, figures 1-6). Because *Hillyardina minuspustulata* and *Hillyardina levis* spp. nov. also display lateral 1P glabellar furrows (see below), Dr. R.A. Fortey (personal communication, 1985) suggested that they might also belong to *Omuliovia*. However, *Omuliovia* has a straight- and parallel-sided rather than anteriorly tapering glabella, which extends to the anterior border; consequently it has no substantial preglabellar field in contrast to the two *Hillyardina* species. Also the anterior border is narrow and convex rather than wide and concave (Chugaeva, 1973; Plate VI, figures 1-6). Furthermore, the pygidial posterior border of *O. mira* is concave rather than convex (Chugaeva, 1973; Plate V, figures 1-3).

Hillyardina minuspustulata sp. nov.
Plate 4, figures 1-9; Plate 5, figures 1-9

1979a *Pachycranium* sp. (in part) Boyce, page 8.
1979b *Hillyardina/Hyperbolochilus* sp. nov. (in part) Boyce

Diagnosis. Anterior border relatively narrow, strongly concave. Prosopon smooth except for pustulose glabella, except in smallest specimens.

Etymology. From the Latin *minus*, less + *pustula* pimple + *ata*, referring to the general lack of pustules.

Stratigraphic range. Lower member of the Boat Harbour Formation, 9.84 to 19.13 m above the base of the Boat Harbour composite section.

Material. Thirty-nine (39) cranidia; twenty-five (25) librigenae; one (1) pygidium.

Holotype. Cranidium, NFM F-127, from BH-9 in the Lower member of the Boat Harbour Formation, at Boat Harbour, western Newfoundland (here designated).

Paratypes. Cranidium, NFM F-128; librigena, NFM F-129; pygidium, NFM F-130; all from the same bed as the holotype (here designated).

Description. Cranidia range from 1.5 to 5 mm in length. Glabella strongly convex and transversely highly vaulted, convex-sided, anteriorly tapering and abruptly rounded to pointed; it extends about seven-tenths total cranidial length. Occipital ring narrow, subtriangular. Weak lateral 1P glabellar furrows variably developed. Preglabellar, axial and occipital furrows distinct, narrow, deep. Preglabellar field wide, about one-ninth to one-eighth total cranidial length, convex, anteriorly steeply downsloping. Median preglabellar furrow variably developed, when present extremely short. Anterior border furrow distinct, narrow, shallow. Anterior border narrow, about one-tenth to one-seventh total cranidial length, abaxially tapering, strongly concave, transversely broadly arched. Anterior fixigenal areas wide, convex, anteriorly steeply downsloping. Anterior portions of facial suture strongly divergent. Palpebral fixigenal areas small, transversely extremely narrow, weakly convex, abaxially upsloping, exsagittally horizontal to gently anteriorly downsloping. Palpebral lobes extremely small but relatively wide for their size, plate-like, short–exsagittal length about three-tenths sagittal glabellar length. Palpebral furrow indistinct, concave-outward. Line through centres of palpebral lobes crosses glabellar sagittal line at about one-half glabellar length from posterior edge of occipital ring. Posterior fixigenal areas generally not preserved but inferred to be transversely long, acutely triangular, convex, posteriorly downsloping from shape of lateral portion of facial sutures on librigenae. Posterior portions of facial suture strongly divergent. Posterior border furrow distinct, narrow, deep. Posterior border wide, convex. On large specimens, prosopon smooth except for scattered glabellar pustules; smaller specimens display pustules on remainder of cranidium as well (see Plate 4 for variation).

Hypostoma unknown.

Librigena with genal field highly convex. Lateral border furrow distinct, narrow, shallow. Lateral border wide–of constant width except posteriorly tapering from posterior border to end of genal spine. Postocular boss variably developed at genal angle. Genal spine short, narrow, abaxially curving posteriorly. Posterior border transversely short, exsagittally wide, convex. Prosopon smooth.

Thorax unknown.

Pygidium acutely triangular, length (1 mm) about one-third maximum width (3 mm). Axial lobe transversely arched, concave-sided, posteriorly strongly tapering and abruptly truncated; it extends at least two-thirds total pygidial length. Five axial rings of posteriorly decreasing sagittal width including terminal ring consisting of an extremely small pair of tubercules. Axial furrows distinct, narrow, deep. Pleural fields poorly preserved but pleural and interpleural furrows developed. Three pairs of pleural furrows are distinct, wide and deep; two pairs of interpleural furrows are distinct, narrow and deep. Posterior border wide–of constant width, about one-third total pygidial length, convex, posteriorly steeply downsloping. Prosopon smooth.

Hillyardina levis sp. nov.
Plate 6, figures 1-10; Plate 7, figures 1-10

1979a *Pachycranium* sp. (in part) Boyce, page 8.
1979a *Hyperbolochilus* sp. Boyce, page 8.
1979b *Hillyardina/Hyperbolochilus* sp. nov. (in part) Boyce.
1983a *Hyperbolochilus* sp. nov. Boyce, page 12.
1983 *Hillyardina/Hyperbolochilus* sp. nov. Boyce *in* Stouge and Boyce; Plate 13, figures 7, 8; Plate 14, figures 1, 2.

Diagnosis. Anterior border wide, concave. Curved dorsal axial spine on fourth or fifth thoracic segment. Pygidial axial

lobe concave-sided, posteriorly tapering and truncated—five axial rings, including terminal ring bearing two tubercules. Prosopon smooth.

Etymology. From the Latin *levis*, smooth, referring to prosopon.

Stratigraphic range. Lower member of the Boat Harbour Formation 38.94 to 66.21 m above the base of the Boat Harbour composite section.

Material. Seventy-two (72) cranidia; ninety (90) librigenae; ten (10) pygidia; one (1) nearly complete exoskeleton lacking librigenae.

Holotype. Cranidium, NFM F-90, from BH-18 in the Lower member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated).

Paratypes. Cranidium, NFM F-93; librigenae, NFM F-92, NFM F-132; pygidium, NFM F-91, all from the same bed as the holotype (here designated). Cranidium, NFM F-133, from BH-23; pygidium, NFM F-134, from BH-30; both in the Lower member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated). Nearly complete exoskeleton, NFM F-131, from the Boat Harbour Formation on Old Ferrolle Island, Brig Bay, western Newfoundland (here designated).

Description. Glabella moderately convex and transversely broadly vaulted, convex-sided, anteriorly tapering and gently rounded; it extends at least three-fifths total cranidial length. Occipital ring sagittally narrow, subtriangular. Preglabellar, axial and occipital furrows distinct, narrow, deep. Weak lateral 1P glabellar furrows variably developed. Preglabellar field wide, about one-tenth total cranidial length, convex, anteriorly steeply downsloping. Anterior border furrow distinct, narrow, shallow, weakly convex-forward. Anterior border wide, about one-seventh total cranidial length, of constant width, strongly concave, flat in anterior view. Anterior fixigenal areas wide, convex, anteriorly steeply downsloping. Anterior portions of facial suture strongly divergent. Palpebral fixigenal areas small, weakly convex, abaxially horizontal to weakly upsloping, exsagittally anteriorly gently downsloping. Palpebral lobes extremely small, plate-like, short, about one-fifth to one quarter sagittal glabellar length. Palpebral furrow indistinct, concave-outward. Line through centres of palpebral lobes crosses glabellar sagittal line at about two-thirds glabellar length from posterior edge of occipital ring. Posterior fixigenal areas transversely long, very acutely triangular, posteriorly downsloping. Posterior border furrow well defined, narrow, deep. Posterior border narrow, convex. Prosopon smooth.

Hypostoma unknown.

Librigena with genal field highly convex. Lateral border furrow distinct, narrow, shallow. Lateral border wide, of constant width, except posteriorly tapering from posterior border to end of genal spine. Genal spine long, narrow, abaxially curving posteriorly. Posterior border transversely short, sagittally narrow, convex. Prosopon smooth.

Thorax composed of nine thoracic segments that are transversely long and sagittally narrow but of equal width. Long, narrow, curved dorsal axial spine on fourth or fifth segment.

Pygidium acutely triangular. Length about one-third maximum width. Axial lobe transversely weakly arched, concave-sided, posteriorly tapering and abruptly truncated; it extends about five-sixths total pygidial length. Five axial rings of equal sagittal width, including terminal ring bearing pair of tubercules. Axial furrows distinct, narrow, deep. Pleural fields flat, horizontal to posteriorly gently downsloping. Four pairs of pleural furrows are distinct, wide, and deep; three pairs of interpleural furrows are distinct, narrow, and deep. Furrows extend to edge of and slightly cut posterior border which is narrow, flat to weakly convex, steeply posteriorly downsloping and flat in posterior view.

Remarks. The collection of a specimen of *Hillyardina levis* lacking only the librigenae (Plate 6, figure 6) allows a comparative assignment of pygidia to other species. The pygidium illustrated by Ross (1951; Plate 19, figures 32, 35) is assigned to *H. semicylindrica* Ross (1951; Plate 16, figures 1-9) on the basis of its matching prosopon of tubercules. The pygidia and thorax illustrated by Ross (1951; Plate 19, figures 33, 36, 37) are assigned to *H. marginauctum* (Ross, 1951; Plate 17, figures 24-27, 30, 31, 34, 35) because of their matching smooth prosopon. The above cranidia and pygidia were all collected from the same horizon in Zone F. The pygidia illustrated by Hintze (1953; Plate VIII, figure 13) and Terrell (1973; Plate 6, figures 4, 7, 8, 10, 11) are assigned to *Hillyardina* sp. A Hintze, of Hintze (1953; Plate VIII, figures 5, 6) and Terrell (1973; Plate 3, figures 1-5).

Thomas and Owens (1978) reviewed the trilobite families Aulacopleuridae and Otarionidae. They synonymized the two families, giving Aulacopleuridae priority over Otarionidae. Thomas and Owens (1978) also subdivided the genus *Otarion* into two subgenera, *Otarion (Otarion)* and *Otarion (Aulacopleura)*.

According to Fortey and Owens (1975) and Thomas and Owens (1978) the Aulacopleuridae evolved in the Tremadoc from hystricurine species. Fortey and Owens (1975, page 231) concluded that *Hystricurus paragenalatus* Ross, *H. genalatus* Ross and *Parahystricurus pustulosus* Ross are probable members of the hystricurine plexus from which *Otarion (Aulacopleura)* (the earliest aulacopleurid) arose, however, *Otarion (Aulacopleura)* may have been derived directly from *Hillyardina*.

The earliest known species of *Otarion (Aulacopleura)* is *Otarion (Aulacopleura) szechuanica* (Lu, 1975, pages 187-189, 393-395; Plate XXXIV, figures 8, 9) from the Tremadoc *Dactylocephalus dactyloides* Zone in the Panho Formation at Wanshengchan of Chunking, Szechuan, China. The latest known species of *Hillyardina* are all of late

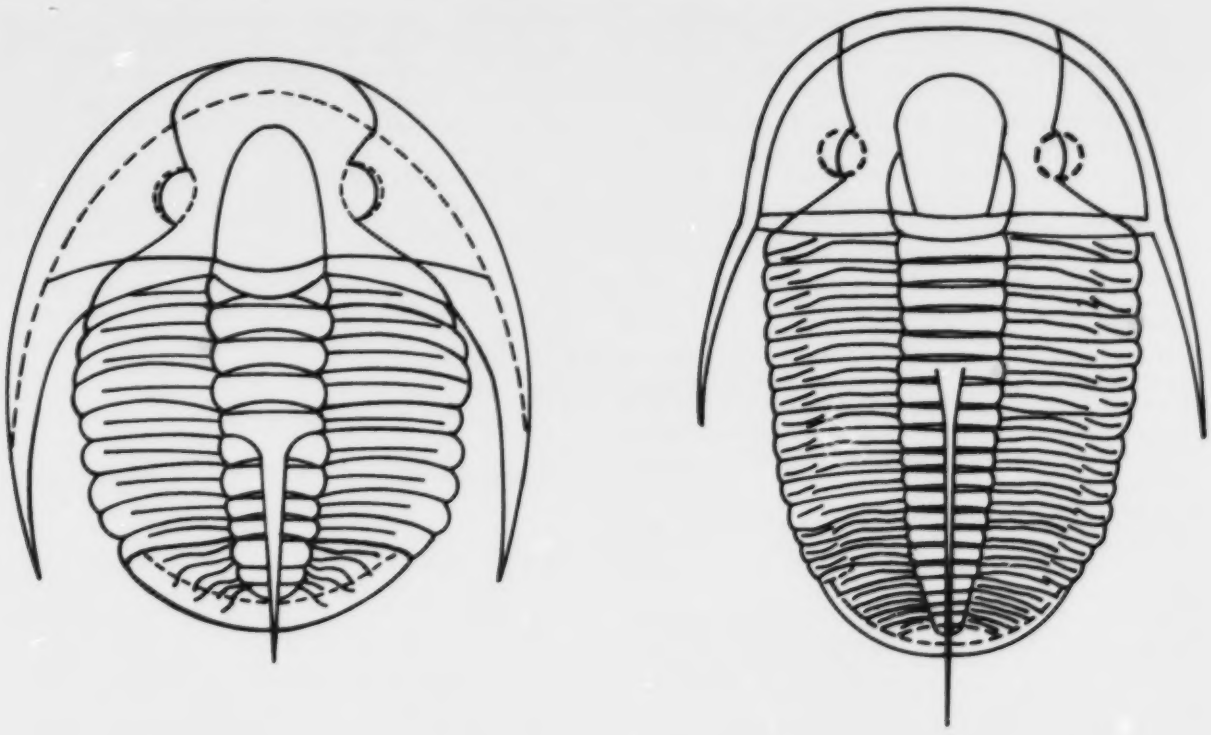


Figure 12. *Reconstructions of* Hillyardina *and* Otarion *(prosopon omitted). Reconstruction of* Hillyardina *(left) by the author, based on Ross (1951; Plate 17, figures 25, 26, 35; Plate 19, figures 33, 37). Reconstruction of* Otarion *(right) modified from Moore (1959; figure 309, 4a).*

Tremadoc Ross–Hintze Zone F age; to date there are no demonstrably Arenig species.

Hillyardina is morphologically similar to *Otarion (Aulacopleura)* (see Figure 12); compare *Hillyardina semicylindrica* Ross (1951; Plate 16, figures 1-9; Plate 19, figures 32, 35), *H. marginauctum* (Ross, 1951; Plate 17, figures 24-27, 30, 31, 34, 35; Plate 19, figures 33, 36, 37), *H.* sp. A Hintze (1953; Plate VIII; figures 5, 6, 13) (Terrell, 1973; Plate 3, figures 1-5; Plate 6, figures 4, 7, 8, 10, 11), *H. minuspustulata* sp. nov. *(this study;* Plate 4, figures 1-9; Plate 5, figures 1-9) and *H. levis (this study;* Plate 6, figures 1-10; Plate 7, figures 1-10) with *Otarion (Aulacopleura) dawanensis* (Lu, 1975; Plate XXXIV, figures 8, 9), *O. (A.) roquemailerensis* Chaubert (Thomas and Owens, 1978; Plate 7, figure 9) and *O. (A.) koninkii* (Barrande) (Thomas and Owens, 1978; Plate 7, figure 10). The common morphological features of *Hillyardina* and *Otarion (Aulacopleura)* include:

1) preglabellar field wide, anteriorly steeply downsloping,
2) palpebral lobes small; palpebral furrows concave-outward,
3) anterior portions of facial suture slightly to strongly divergent; posterior portions strongly divergent,
4) posterior fixigenal areas acutely triangular,
5) cranidial prosopon pustulose to smooth,
6) genal field of librigena highly convex; length of genal spines similar,
7) thoraxes with narrow axes, broad pleural areas; long, narrow, curved dorsal axial spine, and
8) pygidium small, semielliptical to triangular; narrow axes, broad pleural areas.

The two genera differ in the following respects:

1) *Hillyardina* has concave-upward anterior border; *Otarion (Aulacopleura)* has convex-upward anterior border,
2) *Hillyardina* generally lacks eye ridges; *Otarion (Aulacopleura)* has faint to well developed eye ridges,
3) *Hillyardina* generally lacks glabellar furrows although *H. minuspustulata* and *H. levis* variably display weak 1P furrows; *Otarion (Aulacopleura)* has strongly developed 1P furrows,
4) *Hillyardina* has 9 thoracic segments; *Otarion (Aulacopleura)* has 13 to 22,
5) *Hillyardina* has axial spine developed on fourth or fifth thoracic segment; *Otarion (Aulacopleura)* has axial spine developed on sixth segment, and
6) *Hillyardina* has 3 to 5 axial rings and 3 to 4 pairs of pleural ribs in pygidium; *Otarion (Aulacopleura)* has 5 to 8 axial rings and 3 to 7 pairs of pleural ribs.

The above differences are regarded as evolutionary changes. The most conspicuous trend is the increased segmentation of the cranidium, thorax and pygidium. This is the *Otarion (Aulacopleura)* type evolutionary trend identified by Fortey and Owens (1975) for the Proetida. Fortey and Owens (1975, page 237) considered that the *Otarion (Aulacopleura)* type, with its multiplication of thoracic segments, hence of thoracic appendages and 'gill branches', may have been connected with a mode of life in deep water under relatively anoxic conditions. They pointed out the occurrence of several species of *Otarion (Aulacopleura)* in deep water lithofacies comparable to those known to previously contain olenid trilobites.

Genus *Hystricurus* Raymond, 1913

1955 *Vermilionites* Kobayashi, pages 452-454.

Type species. Bathyurus conicus Billings, 1859 from the Beekmantown Group at St. Timothy, Quebec.

Diagnosis. Glabella straight- to convex-sided, anteriorly tapering. Occipital ring subrectangular; occipital spine variably developed. Preglabellar, occipital and axial furrows well defined, deep. Lateral glabellar furrows absent or represented by shallow pits in axial furrows or by smooth patches on sides of glabella. Anterior border furrow distinct, narrow to wide, shallow to deep. Anterior border narrow, strongly convex to subtubular, convex-forward. Eye ridges generally not developed. Palpebral lobes large, long; exsagittal length one-third to one-half sagittal glabellar length, always extending to rear of glabellar midpoint, crescentic to semicircular. Line through centres of palpebral lobes crosses glabellar sagittal line at or very slightly forward of glabellar midpoint. Posterior border furrows well defined, wide, deep. Prosopon of tubercules. Librigena have a moderately convex genal field. Lateral border furrow distinct, narrow to wide, shallow to deep. Lateral border narrow, convex to subtubular. Genal spine long, convex. Prosopon of tubercules. Thorax with eleven segments. Axial lobe about one-third to one-half total width. Proximal half of each pleuron horizontal; distal half flexed gently to steeply downward. Tips of pleurae spined or bluntly rounded. Pygidium subtriangular, semielliptical to semicircular. Axial lobe moderately to strongly convex, posteriorly tapering and abruptly rounded to truncated. Four or five axial rings including terminal ring. Axial and axial ring furrows well defined, deep. Pleural and interpleural furrows variably defined. Three or four pairs of pleural ribs. Prosopon of tubercules. Diagnosis modified from Ross (1951, pages 39-40).

Remarks. Kobayashi (1955, pages 452-454; Plate VI, figure 4; Plate IX, figure 2) proposed the new genus *Vermilionites* based on one cranidium of the new species *bisulcatus* from the Lower Ordovician McKay Group of British Columbia. The genotype, curated at the Geological Survey of Canada has been examined by the author. In size, shape, convexity and prosopon type the anterior border, glabella and palpebral lobes of *V. bisulcatus* favourably compare with those of *Hystricurus oculilunatus* Ross with which it is synonymized. Kobayashi (1955) erroneously used the presence of faint eye ridges to separate *V. bisulcatus* from *Hystricurus*. In fact, *H. oculilunatus* displays a vague alignment of tubercules suggestive of remnant ocular ridges.

Based on the reasons above, *Vermilionites* Kobayashi, 1955 is considered to be a junior subjective synonym of *Hystricurus* Raymond, 1913.

The narrow, convex to subtubular anterior border, the general absence of eye ridges, the distinctive prosopon of tubercules and the markedly different pygidia readily distinguish *Hystricurus* from *Paraplethopeltis* Bridge and Cloud, 1947.

Hystricurus oculilunatus Ross, 1951
Plate 8, figures 1-8; Plate 9, figures 1-10;
Plate 10, figures 1-10; Plate 11, figures 1-13.

1889a *Bathyurus conicus* Billings; Whitfield, pages 61-62; Plate 13, figures 15-21.
1951 *Hystricurus oculilunatus* Ross, n. sp; Ross, pages 47-48; Plate 10, figures 1-3, 5, 8, 9, 12.
1951 Unassigned pygidium from Zone 'F', Ross; Plate 17, figures 23, 28, 29.
1955 *Vermilionites bisulcatus* Kobayashi, new genus and species; Kobayashi, pages 452-454; Plate VI, figure 4; Plate IX, figure 2.
1955 *Hystricurus platypleurus* Kobayashi, new species; Kobayashi, page 454; Plate VI, figure 6.
1959 *Hystricurus oculilunatus* Ross; Berg and Ross, page 112; Plate 21, figure 2.
1959 *Hystricurus conicus* (Billings); Poulsen *in* Moore, pages O277, O278; Figures 204-4a,b.
1962 *Hystricurus conicus* (Billings); Welby, pages 78, 79; Plate XIII, figure 10.
1968c *Hystricurus* cf. *conicus* (Billings); Flower, page 33; Plate 7, figure 4.
1973 *Hystricurus acumensis* Ross (in part); Terrell, page 73; Plate 1, figure 8 not figures 1, 4-6.
1973 *Hystricurus oculilunatus* Ross (in part); Terrell, page 73; Plate 1, figures 11, 12, 14 not figures 15, 16.
1978 *Hystricurus* sp. 2; Boyce, page 83.
1979a *Hystricurus* cf. *H. oculilunatus* Ross; Boyce, page 8.
1979b *Hystricurus oculilunatus* Ross (in part); Boyce.
1983 *Hystricurus oculilunatus* Ross; Boyce *in* Stouge and Boyce; Plate 12, figures 5, 6.
1983b *Hystricurus oculilunatus* Ross; Boyce, pages 104-110; Plate 6, figures 7, 8; Plate 7, figures 1-8; Plate 8, figures 1-3.

Diagnosis. Glabella slightly bell-shaped, convex sided. Anterior border narrow, highly convex, smooth. Palpebral lobes large, crescentic. Posterior fixigenae transversely long. Librigena lacks posterior border. Lateral border highly convex, smooth (internal mould) to terrace-ridged (external mould), abaxially widening to posterior margin. Genal spine continuous with lateral border, long, highly convex, smooth (internal mould) to terrace-ridged (external mould),

posteriorly tapering, projects outward from posterior margin. Pygidium with prominent pair of tubercules on terminal ring. Four pairs of pleural ribs—three pairs displaying paired tubercules; posterior pair small, poorly developed, no tubercules. Posterior border well defined, narrow, flat to convex-outward, smooth (internal mould) to terrace-ridged (external mould), posteriorly gently downsloping, straight in posterior view with small postaxial arch. Prosopon of coarse tubercules.

Stratigraphic range. Lower member of the Boat Harbour Formation, 2.31 to 50.64 m above the base of the Boat Harbour composite section.

Material. Seventy-one (71) cranidia; forty-eight (48) librigenae; thirty-four (34) pygidia.

Holotype. Cranidium, YPM 17960 (the original of Ross, 1951; Plate 10, figures 2,3,5—by monotypy).

Description. Glabella highly convex, transversely moderately vaulted, slightly bell-shaped, convex-sided, anteriorly tapering and broadly rounded; it extends about four-fifths total cranidial length. Occipital ring sagittally narrow, subrectangular, abaxially curving forward. Occipital and axial furrows well defined, wide, deep; preglabellar furrow shallower. Lateral glabellar furrows not developed. Preglabellar field narrow, convex, anteriorly moderately steeply downsloping, length variable but averages about one-tenth total cranidial length. Anterior border furrow distinct, wide, deep. Anterior border transversely long, narrow, highly convex, smooth (internal mould) to terrace-ridged (external mould), in anterior view transversely gently arched. Anterior fixigenal areas wide, convex, anteriorly moderately steeply downsloping. Palpebral fixigenal areas only slightly wider than anterior fixigenal areas, abaxially horizontal to very gently upsloping, exsagittally anteriorly gently downsloping. Vague alignment of tubercules suggests remnant ocular ridges. Palpebral lobes large, long—exsagittal length about one-half sagittal glabellar length, crescentic. Palpebral furrow distinct, narrow, shallow. Line through centres of palpebral lobes crosses glabellar sagittal line at about one-half glabellar length from posterior edge of occipital ring. Posterior fixigenal areas long, narrow, convex, posteriorly steeply downsloping. Posterior border furrows well defined, wide, deep. Prosopon of coarse tubercules. Anterior border narrow, all furrows wider, deeper on internal mould than on external mould.

Hypostoma unknown.

Librigena with genal field moderately convex. Lateral border furrow distinct, wide, deep. Lateral border highly convex, smooth (internal mould) to terrace-ridged (external mould), abaxially widening to posterior margin. Genal spine continuous with lateral border, long, highly convex, smooth (internal mould) to terrace-ridged (external mould); it projects outward from posterior margin. Lateral border furrows well defined, wide, deep. No posterior border or posterior border furrows. Prosopon of coarse tubercules except for lateral border and genal spine.

Pygidium moderately convex, semicircular, length about one-half maximum width at posterior end of articulating facets. Axial lobe transversely gently arched, posteriorly gently tapering and truncated; it extends to posterior border, in profile posteriorly very gently downsloping. Three well defined axial rings of even sagittal width; terminal ring with prominent pair of tubercules. Axial and pleural furrows distinct, wide, deep. Pleural furrows curve progressively backwards and stop at posterior border. Four pairs of pleural ribs—three pairs displaying paired tubercules, posterior pair small, poorly developed, no tubercules. In posterior view, pleural ribs and tubercules form nearly horizontal surface. Posterior border well defined, narrow, flat to convex-outward, smooth (internal mould) to terrace-ridged (external mould). Posterior border furrow distinct, narrow, shallow. Prosopon of coarse tubercules except for posterior border. On internal moulds surface tuberculation is less pronounced and all furrows are wider.

Remarks. Although in western Newfoundland *Hystricurus oculilunatus* is known mostly from internal moulds, the smooth, convex anterior border, the slightly bell-shaped, convex-sided glabella, the large, crescentic palpebral lobes, the characteristic librigenae and the distinctive pygidium readily distinguish this species from all other presently known *Hystricurus* species.

Although Ross (1951, pages 47-48; Plate 10, figures 1-3, 5, 8-9, 12) proposed the species, *H. oculilunatus* was originally described and illustrated by Whitfield (1889a, pages 61-62; Plate 13, figures 15, 16, 18-21) from 'the subcrystalline layers of the Calciferous about one and a half miles north of Beekmantown Station on the Delaware and Hudson Railroad, three miles north of Plattsburgh, N.Y.' (Whitfield, 1889a, pages 42, 62). Whitfield (1889a) assigned his specimens to *Bathyurus conicus* Billings, 1859, which is the type species of *Hystricurus* Raymond (1913, page 60). This assignment was accepted by Poulsen *in* Moore (1959, pages O277, O278; Figures 204-4a,b) and Welby (1962, pages 78, 79; Plate XIII, figure 10) as well as by Flower (1968c, page 33; Plate 7, figure 4) who reported a cranidium of *H.* cf. *conicus* from the Fort Ann Formation (Beekmantown Group) of Fort Ann, New York. *Hystricurus conicus* was originally described and illustrated by Billings (1859, page 366; Figure 12c) from the Beekmantown Group at St. Timothy, Quebec. It differs from *H. oculilunatus* in that it possesses a more abruptly rounded glabella and a wider preglabellar field.

Ross (1951, pages 47-48; Plate 10, figures 1-3, 5, 8, 9, 12), described *H. oculilunatus* from Ross—Hintze Zone F in the Garden City Formation of northeastern Utah and illustrated a pygidium from the same horizon (Ross, 1951; Plate 17, figures 23, 28, 29) which is assigned to that species. The cranidial, librigenal and pygidial borders of the Utah specimens display fine terrace-ridges, whereas the western Newfoundland and New York specimens do not. This is attributed to the fact that the latter material is represented primarily by internal moulds. Terrace-ridges are generally preserved only on external moulds.

Vermilionites bisulcatus Kobayashi (1955, page 452-454; Plate VI, figure 4; Plate IX, figure 2) and *Hystricurus platypleurus* Kobayashi (1955, page 454; Plate VI, figure 6) from the Lower Ordovician McKay Group in British Columbia were established on one cranidium and one pygidium, respectively. Kobayashi's poorly preserved type material at the Geological Survey of Canada has been examined. Based on the examination, the two species are synonymized with *H. oculilunatus* Ross.

Sando (1957, pages 136-137; Plate 11, figure 4) described and illustrated as *Hystricurus?* sp., from the Stonehenge limestone (Beekmantown Group) of Maryland, a pygidium similar but not identical to *H. oculilunatus*.

Berg and Ross (1959, page 112; Plate 21, figure 2), illustrated an incomplete cranidium of *H. oculilunatus* from the Manitou Formation of Colorado.

Terrell (1973, page 73; Plate 1, figures 11, 12, 14) illustrated *H. oculilunatus* from Ross–Hintze zones E and F in the lower Fillmore Formation (Pogonip Group) of western Utah but incorrectly assigned its pygidium (Terrell, 1973; Plate 1, figure 8) to *Hystricurus acumensis* (= *H. acumennasus)* Ross.

In summary, *H. oculilunatus* is a widespread, biostratigraphically important species. Besides the Boat Harbour Formation (St. George Group) of western Newfoundland it occurs in:

1) the Fort Ann Formation (Beekmantown Group) of Plattsburgh and Fort Ann, New York (Whitfield, 1889a; Flower, 1968c)–in the type deposits of the Canadian Series (Fahraeus, 1977b; Flower, 1964; Whittington, 1968),
2) the McKay Group of British Columbia (Kobayashi, 1955),
3) the Manitou Formation of Colorado (Berg and Ross, 1959),
4) Zone F in the Garden City Formation of northeastern Utah (Ross, 1951), and
5) Zones E and F in the lower Fillmore Formation (Pogonip Group) of western Utah and eastern Nevada (Hintze, 1953; Terrell, 1973).

Hystricurus deflectus Heller, 1954
Plate 12, figures 1-10; Plate 13, figures 1-10

1954 *Hystricurus deflectus* Heller, n. sp; Heller, pages 43-44; Plate XVIII, figure 6.
1954 *Hystricurus* sp. Heller, pages 44-45; Plate XVIII, figures 7, 8 *not* figures 9, 18.
1978 *Hystricurus* sp. 1 Boyce, page 83.
1979a *Hystricurus* sp. Boyce, page 8.
1979b *Hystricurus oculilunatus* Ross (in part); Boyce.
1983 *Hystricurus* sp. nov. Boyce *in* Stouge and Boyce; Plate 12, figures 7, 8.
1983b *Hystricurus pseudoculilunatus* sp. nov. Boyce, pages 111-115; Plate 8, figures 4-8.

Diagnosis. Glabella straight-sided. Median preglabellar furrow. Palpebral lobes large, semicircular. Librigenae with posterior border transversely short, smooth, distinct. Genal spine short. Pygidium has a subdued pair of tubercules on terminal ring. Posterior border almost nonexistent but well defined, narrow, smooth, posteriorly steeply downsloping to vertical, in posterior view transversely gently arched.

Stratigraphic range. Lower member of the Boat Harbour Formation, 38.94 to 59.31 m above the base of the Boat Harbour composite section.

Material. Thirty-four (34) cranidia; sixty-seven (67) librigenae; thirty-four (34) pygidia.

Holotype. Pygidium, UMo 10329, from a chert zone in the middle of the Roubidoux Formation, just north of New Bryant, Douglas County, Missouri (the original of Heller, 1954; Plate XVII, figure 6, by monotypy).

Description. Glabella highly convex, transversely strongly vaulted, straight-sided to very slightly convex-sided in larger individuals, anteriorly tapering and broadly truncated; it extends about four-fifths total cranidial length. Occipital ring sagittally narrow, rectangular. Preglabellar and axial furrows well defined, narrow, deep; occipital furrow wider. Lateral glabellar furrows not developed. Preglabellar field narrow, convex, anteriorly steeply downsloping, about one-tenth cranidial length. Median preglabellar furrow narrow, shallow, distinct. Anterior border furrow distinct, wide, deep, slightly narrower than occipital furrow, broadly convex-forward. Anterior border narrow, highly convex, smooth, in anterior view transversely strongly arched. Anterior fixigenal areas wide, convex, anteriorly steeply downsloping. Palpebral fixigenal areas wider than anterior fixigenal areas, abaxially upsloping, exsagittally anteriorly steeply downsloping. Palpebral lobes large, long–exsagittal length about one-half sagittal glabellar length, semicircular. Palpebral furrow distinct, narrow, shallow. Line through centres of palpebral lobes crosses glabellar sagittal line at about five-eighths glabellar length from posterior edge of occipital ring. Posterior fixigenal areas long, convex, posteriorly steeply downsloping. Posterior border furrows well defined, wide, deep. Prosopon of coarse tubercules reflected on internal moulds.

Hypostoma unknown.

Librigena has a moderately convex genal field. Lateral border furrow distinct, wide, deep. Lateral border highly convex, smooth (internal mould) to terrace-ridged (external mould), abaxially widening to and merging with posterior border. Genal spine continuous with lateral border, short, highly convex, smooth (internal mould) to terrace-ridged (external mould); it projects outward from posterior border. Posterior border distinct, transversely short. Posterior border furrow distinct, shallow. Prosopon of coarse tubercules except for lateral border and genal spine.

Thorax unknown.

Pygidium moderately convex, semielliptical, length about one-half maximum width at posterior end of articulating facets. Axial lobe moderately convex, transversely gently arched, posteriorly gently tapering and truncated; it extends to posterior border, in profile posteriorly very gently downsloping. Three well defined axial rings of even sagittal width, terminal ring having subdued pair of tubercules. Axial and pleural furrows well defined, narrow, deep. Pleural furrows curve progressively backward and stop at posterior border. Four pairs of pleural ribs—three pairs displaying paired tubercules; posterior pair small, poorly developed, no tubercules. In posterior view, pleural ribs form transversely downward-curving surface. Posterior border well defined, narrow, flat to slightly convex-outward, smooth, posteriorly steeply downsloping to vertical, in posterior view transversely gently arched. Prosopon of coarse tubercules except for posterior border.

Discussion. The median preglabellar furrow, the straight-sided anteriorly tapering and broadly truncate glabella, the short posterior fixigenal areas and the greater overall degree of convexity of the cranidium readily distinguishes *H. deflectus* from *H. conicus* and *H. oculilunatus*, the species it most resembles. In addition, the shorter genal spine and the narrower, vertical pygidial border of *H. deflectus* readily distinguishes it from *H. oculilunatus*.

The close resemblance of *H. oculilunatus* and *H. deflectus*, as well as the fact that the latter succeeds the former in the Boat Harbour sequence, suggests that *H. deflectus* is an evolutionary descendent of *H. oculilunatus*. However, because these two species are generally not found together in the same environment, it is suggested that evolution took place by allopatric speciation (Eldredge, 1971; Mayr *et al.*, 1953). Furthermore, *O. deflectus* records evolutionary trends that eventually cuiminated in the bathyurid genus *Petigurus* Raymond, 1913. These trends are:

1) increased convexity of cranidium and pygidium, especially axial region,
2) straighter, more parallel-sided glabella, narrower preglabellar area, and shorter anterior border,
3) glabella increasingly overhangs preglabellar area,
4) stronger and increased segmentation of axial rings and pleural ribs in pygidium,
5) increased narrowing and steepening of posterior pygidial border, and
6) increased transverse arching of pygidial border.

South of the study area, in the Port aux Choix–Eddies Cove West region, specimens of *Petigurus* sp. nov. A have been collected (Boyce, 1985); the species is morphologically intermediate between *Hystricurus deflectus* Heller and *Petigurus nero* (Billings).

Hystricurus crassilimbatus Poulsen, 1937
Not figured

1937 *Hystricurus crassilimbatus* n. sp, Poulsen, pages 47-48; Plate 5, figures 5-8.
1946 *Hystricurus crassilimbatus* Poulsen; Poulsen, page 327; Plate XXII, figure 18.
1966 *Hystricurus crassilimbatus* Poulsen; Lochman, page 533; Plate 65, figure 41.
1986 *Hystricurus* sp. cf. *H. crassilimbatus* Poulsen; Boyce, page 163.

Diagnosis. Anterior margin straight to concave-forward. Anterior border furrow concave-forward. Anterior border convex-upward, abaxially tapering. Anterior branches of facial suture almost straight, strongly converging. Glabella strongly convex. Preglabellar area not developed. Fixigenae narrow. Palpebral lobes small. Prosopon of coarse tubercules.

Stratigraphic range. Barbace Cove Member of the Boat Harbour Formation, 74.34 to 75.89 m above the base of the Boat Harbour composite section.

Material. Ten (10) cranidia.

Holotype. Cranidium, from the Cape Weber Formation at the upper end of Devon Canyon in east-central Greenland (the original of Poulsen, 1937; Plate 5, figure 7, by monotypy).

Remarks. The Boat Harbour material adds no new information to the concept of this species. As Poulsen (1937) provided an adequate description of *H. crassilimbatus*, it is not repeated here.

Genus *Parahystricurus* Ross, 1951

Type species. Parahystricurus fraudator Ross, 1951, from the Garden City Formation of northeastern Utah.

Diagnosis. See Ross (1951, pages 56, 57) for diagnosis of cranidium, librigenae. Pygidium oblong, subtriangular to semielliptical. Up to four axial rings. Pleural and interpleural furrows well developed, prosopon smooth.

Parahystricurus smithiae sp. nov.
Plate 14, figures 1-8; Plate 15, figures 1-8; Plate 16, figures 1-10

1979a *Parahystricurus* sp. Boyce, page 8.
1979b *Parahystricurus* sp. nov. Boyce.
1983a *Parahystricurus* sp. nov. Boyce, page 11.
1983 *Parahystricurus* sp. nov. Boyce *in* Stouge and Boyce, Plate 13, figures 5, 6.

Diagnosis. Cranidium highly convex. Glabella strongly convex, elliptical. Two, probably three, pairs of lateral

glabellar furrows—weakly defined, wide, shallow. Median preglabellar furrow weakly defined, wide, shallow. Anterior border distinct but extremely narrow, flat to weakly convex, smooth. Posterior fixigenal areas long, narrow, subtriangular. Posterior border furrow weakly defined, wide, shallow. Cranidial prosopon of mixed fine pustules and coarser tubercules. Pygidium oblong, semielliptical. Four axial rings (including terminal ring) of posteriorly decreasing sagittal width. Three pairs of pleural furrows—distinct, wide, shallow. Three pairs of interpleural furrows—well defined, narrow, deep. Posterior border weakly defined but distinct, moderately narrow, flat, smooth, posteriorly steeply downsloping. Pygidial prosopon smooth.

Etymology. For J.L. Smith.

Stratigraphic range. Lower member of the Boat Harbour Formation, 38.94 to 66.14 m above the base of the Boat Harbour composite section.

Material. Seventy-six (76) cranidia; thirty-four (34) librigenae; three (3) pygidia.

Holotype. Cranidium, NFM F-88 from BH-30 in the Lower member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated).

Paratypes. Cranidium, NFM F-142; librigena, NFM F-144; pygidium, NFM F-89, from the same bed as the holotype (here designated). Librigena, NFM F-143, from BH-18 in the Lower member of the Boat Harbour Formation at Boat Harbour; western Newfoundland (here designated).

Description. Glabella highly convex, transversely strongly vaulted, elliptical, convex-sided, anteriorly abruptly rounded; it extends about nine-tenths total cranidial length. Occipital ring narrow, subtriangular. Two, probably three, pairs of lateral glabellar furrows—weakly defined, wide, shallow. Posterior pair directed diagonally backward from axial furrows, become progressively shallower. Anterior pairs directed transversely across glabella, about one-third length of posterior pair. Occipital and axial furrows well defined, wide, deep. Axial furrows become markedly narrower and shallower in front of anterior pair of glabellar furrows, forming preglabellar furrow. Preglabellar field narrow, convex, anteriorly steeply downsloping. Median preglabellar furrow weakly defined, wide, shallow, about one-twentieth total cranidial sagittal length. Anterior border furrow distinct, narrow, shallow, convex-forward except for immediately anterior portion of preglabellar field where intersection with median furrow results in abrupt forward-concavity. Anterior border transversely long, sagittally narrow, flat to weakly convex, smooth, abaxially strongly tapering, in anterior view transversely gently arched. Anterior fixigenal areas wide, convex, anteriorly steeply downsloping. Palpebral fixigenal areas about the same width as anterior fixigenal areas, abaxially horizontal to very gently upsloping, exsagittally horizontal to very gently downsloping. Palpebral lobes not preserved; palpebral furrows wide, shallow, suggest palpebral lobes relatively small—exsagittal length about one-quarter to three-tenths sagittal glabellar length. Line through centres of palpebral furrows crosses glabellar sagittal line at about one-half glabellar length from posterior edge of occipital ring. Posterior fixigenal areas long, narrow, triangular, weakly convex, posteriorly moderately steeply downsloping. Posterior border furrows weakly defined, wide, shallow. Posterior border extremely narrow, convex. Prosopon of mixed fine pustules and coarser tubercules.

Hypostoma unknown.

Librigena with genal field moderately convex. Lateral border furrow distinct, narrow, shallow. Lateral border narrow—of constant width, convex. Genal spine continuous with lateral border, convex; it projects outward from posterior margin. No posterior border or posterior border furrow. Prosopon of mixed fine pustules and coarser tubercules.

Thorax unknown.

Pygidium moderately convex, oblong, semielliptical, length about two-fifths to nine-twentieths maximum width at posterior end of articulating facets. Axial lobe weakly convex, transversely weakly arched, posteriorly gently tapering and truncate, extends about three-quarters total pygidial length. Four distinct axial rings (including terminal ring) of posteriorly decreasing sagittal width. Axial ring furrows abaxially deepen markedly. Axial furrows distinct, narrow, deep. Three pairs of pleural furrows—distinct, wide, shallow. Three pairs of interpleural furrows—well defined, narrow, deep. Pleural and interpleural furrows curve very gently backward and stop slightly past posterior border. Posterior border weakly defined but distinct, moderately narrow, flat, smooth, posteriorly steeply downsloping. Prosopon smooth.

Remarks. When Ross originally proposed *Parahystricurus*, he stated that no pygidia could be assigned with certainty to the genus (Ross, 1951, page 57). However, he illustrated a pygidium (Ross, 1951; Plate 19, figures 6, 11, 15) which he thought was possibly referable to *P. carinatus* Ross (1951, pages 60-61; Plate 13, figures 23-27, 30-32, 35-37). This author has been able to associate the cranidia and pygidia of *Parahystricurus* with certainty. Fossil horizon BH-30 in the Boat Harbour sequence yielded only three trilobite species, namely *P. smithiae*, *Hillyardina levis* and *Randaynia saundersi*. Since *H. levis* and *R. saundersi* were already known from nearly complete individuals (Plate 6, figure 6; Plate 36, figure 4, respectively) and *R. saundersi* is a much larger trilobite than *P. smithiae*, it was a simple matter to assign the small pygidia obtained to *P. smithiae*. The general similarity of Ross' illustrated pygidium to that of *P. smithiae* (Plate 16, figure 7) suggests that his proposed assignment of it to *P. carinatus* was correct.

The highly convex, elliptical glabella with its two or three faint pairs of lateral glabellar furrows, the long, narrow, weakly convex posterior fixigenal areas, and the characteristic prosopon of the cranidium, readily distinguish *P. smithiae* from most described species of *Parahystricurus*. The species

Hystricurus elevatus Heller (1954, pages 42-43; Plate XVIII, figures 1-3, 10-12) closely resembles *P. smithiae*. This species, which is assigned to *Parahystricurus*, differs from *P. smithiae*, however, in that it lacks lateral glabellar furrows. Sando (1957, page 137; Plate 11, figure 3) described and illustrated an incomplete cranidium of *Parahystricurus* from the Rockdale Run Formation (Beekmantown Group) of Maryland, which closely resembles *P. smithiae*. This cranidium probably represents a new species of *Parahystricurus*, although Sando assigned it to *Hystricurus*. It differs from *P. smithiae* in that it is less convex, has a wider preglabellar area and is more strongly furrowed than *P. smithiae*.

Genus Paraplethopeltis Bridge and Cloud, 1947

Type species. Paraplethopeltis obesa Bridge and Cloud, 1947, from the Tanyard Formation of central Texas.

Diagnosis. Glabella strongly convex, straight- to convex-sided, anteriorly tapering. Occipital ring subrectangular; occipital spine variably developed. Preglabellar and axial furrows well defined, deep. Occipital furrow faint, shallow to well defined, deep. Lateral glabellar furrows not developed. Anterior border furrow indistinct to well defined, narrow to wide, shallow to deep. Anterior border narrow, concave, flat to convex, convex-forward. Eye ridges faint. Palpebral lobes small to large, short to long, crescentic. Posterior border furrows faint, shallow to well defined, deep. Cranidial prosopon smooth. Librigena with moderately convex genal field. Lateral border furrow indistinct to well defined, narrow to wide, shallow to deep. Lateral border narrow to wide, concave, flat to weakly convex. Librigenal prosopon smooth. Pygidium subtriangular to semielliptical. Axial lobe wide, moderately to strongly convex, posteriorly tapering and abruptly to broadly rounded; end merges into posterior margin. Four or five axial rings including terminal ring. Axial and axial ring furrows well defined, deep. Pleural and interpleural furrows well defined, deep. Three or four pairs of pleural ribs. Posterior border furrow faint. Posterior border narrow, convex to concave. Pygidial prosopon smooth. Diagnosis modified and expanded from Lochman-Balk *in* Moore (1959, page O410).

Remarks. Lochman-Balk *in* Moore (1959, page O410) assigned *Paraplethopeltis* to the family Plethopeltidae Raymond, 1925. *Paraplethopeltis* closely resembles *Hystricurus* Raymond, 1913, being distinguished chiefly by its less convex anterior border, the presence of faint eye ridges and its distinctive smooth prosopon. For this reason *Paraplethopeltis* is assigned to the subfamily Hystricurinae Hupé, 1953.

Hintze (1953, page 201) questionably assigned to *Paraplethopeltis* two species having well defined anterior borders, i.e. *P.? genacurvis* Hintze (1953, pages 202-204; Plate VII, figures 1-5) and *P.? genarectus* Hintze (1953, page 204; Plate VII, figures 6-9). A comparison of illustrated pygidia of the two species (Hintze, 1953; Plate VII, figures 4, 5, 9) with that of *P. obesa* Bridge and Cloud (1947; Plate 2, figures 1-7, 12-14) suggests the three specimens are congeneric; the pygidia of these species are fully comparable with respect to size, shape, convexity, number of axial rings, and number and style of pleural and interpleural furrows. Consequently *P.? genacurvis* and *P.? genarectus* are assigned to *Paraplethopeltis*. The presence of a well developed anterior border in *Paraplethopeltis* is regarded as a derived or secondary evolutionary character.

Hintze (1953, page 201) identified several other species as being congeneric with *P.? genacurvis* and *P.? genarectus* and hence with *Paraplethopeltis* (see above). These species are *Hystricurus?* sp. E Ross (1951; Plate 15, figures 10, 11, 13, 14), *Hystricurus?* sp. I Ross (1951; Plate 17, figures 1-3), *Pachycranium?* sp. Ross (1951; Plate 17, figures 4-6, 9-11, 14, 15) and *Hystricurus nudus* Poulsen (1937; Plate 2, figure 10). *Hystricurus?* sp. E is probably conspecific with *Paraplethopeltis genacurvis*, based on the close similarities of their cranidia and pygidia. *Hystricurus?* sp. I probably represents a new species of *Parahystricurus*, as it has a prosopon of tubercules. *Pachycranium?* sp. may represent *Paraplethopeltis generectus*, whereas the librigena illustrated by Ross (1951, Plate 17, figures 6, 14) may belong to *Hystricurus?* sp. I, because of its prosopon of tubercules. *Paraplethopeltis nudus* is a distinctive species with a narrow concave-upward anterior border.

The following species are also assigned to *Paraplethopeltis:*

Bathyurus cordai Billings, 1859 *(this study,* Plate 17, figures 1-4)
Bathyurus seelyi Whitfield, 1889a
Hystricurus? sp. aff. *H.? genacurvis* (Hintze); Berg and Ross (1959)
Hystricurus cf. *H. oculilunatus* Ross; Ross (1970)

The earliest species of *Paraplethopeltis* (i.e., *P. obesa* Bridge and Cloud, 1947; *P. depressa* Bridge and Cloud, 1947; and *P. carinifera* Flower, 1968b), which are earliest Ordovician in age, are characterized by poorly developed anterior borders, relatively small palpebral lobes and weakly defined occipital rings. The Trempealeauan (latest Cambrian) genus *Plethopeltis* Raymond, 1913 also exhibits these features. The main difference between the two genera is the greater degree of segmentation in the pygidium of *Paraplethopeltis*. The fact that *Paraplethopeltis* biostratigraphically succeeds *Plethopeltis* coupled with the close resemblance of the two genera suggests that *Paraplethopeltis* evolved from *Plethopeltis*.

Paraplethopeltis seelyi (Whitfield, 1889a)
Plate 17, figures 5-8; Plate 18, figures 1-8;
Plate 19, figures 1-8; Plate 20, figures 1-5

1889a *Bathyurus seelyi* n. sp. Whitfield, pages 62-63; Plate 13, figures 8-14.
1913 *Hystricurus cordai* (Billings); Raymond, page 61.
1978 *Hystricurus (Paraplethopeltis?)* cf. *H. (P?) millardensis* and/or *Hystricurus? (Paraplethopeltis?) genacurvis* (Hintze, 1953); Boyce, page 83.
1979a *Hystricurus cordai* (Billings); Boyce, page 8.
1979b *'Hystricurus' cordai* (Billings); Boyce.

1983a *Paraplethopeltis seelyi* (Whitfield); Boyce, pages 11, 12.
1983 *Paraplethopeltis seelyi* (Whitfield); Boyce *in* Stouge and Boyce; Plate 15, figures 6-8.
1983b *Paraplethopeltis seelyi* (Whitfield); Boyce, pages 126-131; Plate 10, figures 2-7; Plate 11, figures 1, 2.

Diagnosis. Cranidium highly convex. Glabella straight-sided, anteriorly tapering and broadly rounded. Eye ridges weakly developed. Palpebral lobes large, long, wide, broadly crescentic. Pygidium with four strongly defined axial rings and four pairs of strongly defined pleural furrows. Interpleural furrows not developed. Posterior border well defined, narrow, concave-outward, vertical.

Stratigraphic range. Lower member of the Boat Harbour Formation, 46.85 to 47.10 m above the base of the Boat Harbour composite section; thrombolitic lime boundstone bed forming the top of Moyrac Island, immediately north of Old Ferrolle Island; Unit 9 of Pratt's (1979) Eddies Cove West Section.

Material. Twenty-three (23) cranidia; eight (8) librigenae; fourteen (14) pygidia.

Lectotype. Cranidium, AMNH 35504 (the original of Whitfield 1889a; Plate 13, figures 11, 12) from the Fort Ann Formation near Plattsburgh, New York (here selected).

Plesiotypes. Cranidium, AMNH 35502; librigena, AMNH 35503; pygidium, AMNH 35505 (the originals of Whitfield, 1889a; Plate 13, figures 8-10, 13,14), from the Fort Ann Formation near Plattsburgh, New York.

Description. Glabella highly convex, transversely moderately vaulted, straight-sided, anteriorly tapering and broadly rounded; it extends about four-fifths total cranidial length. Occipital ring sagittally wide, rectangular. Preglabellar and axial furrows well defined, narrow, deep; occipital furrow slightly less so. Lateral glabellar furrows not developed. Preglabellar field narrow, convex, anteriorly steeply downsloping, about one-fourteenth total cranidial length. Anterior border furrow well defined, narrow, deep; in front of glabella straight to slightly concave-forward, abaxially convex-forward. Anterior border transversely long, relatively wide, flat to abaxially slightly convex, horizontal to anteriorly very gently downsloping, in anterior view transversely broadly arched. Anterior fixigenal areas wide, convex, anteriorly steeply downsloping. Palpebral fixigenal areas only slightly wider than anterior fixigenal areas, abaxially horizontal to very gently upsloping, exsagittally anteriorly very gently downsloping. Eye ridges faint, extremely narrow. Palpebral lobes large, long—exsagittal length about two-fifths sagittal glabellar length, wide, broadly crescentic. Palpebral furrow distinct, narrow, shallow. Line through centres of palpebral lobes crosses glabellar sagittal line at about one-half glabellar length from posterior edge of occipital ring. Posterior fixigenal areas narrow, convex, posteriorly moderately steeply downsloping. Posterior border furrow well defined, narrow, deep. Posterior border flat to slightly convex, posteriorly gently upsloping. Prosopon smooth.

Hypostoma unknown.

Librigena with genal field moderately convex. Lateral border furrow well defined, narrow, deep, abaxially shallowing. Lateral border wide, convex, abaxially expanding. Genal spine short, stubby. Posterior border furrow and posterior border not developed. Prosopon smooth.

Thorax unknown.

Pygidium highly convex, subelliptical, length about one-half to three-fifths maximum width at posterior end of articulating facets. Axial lobe moderately convex, transversely moderately arched, posteriorly gently tapering and abruptly rounded; it extends about nine-tenths total pygidial length. Four well defined axial rings (including terminal ring) of posteriorly decreasing sagittal width. Axial and axial ring furrows distinct, narrow, deep; axial ring furrows abaxially become shallower. Four pairs of pleural furrows, equally distinct, narrow, deep, curve progressively backward and stop at posterior border. Four pairs of well defined pleural ribs; interpleural furrows not developed. Posterior border well defined, narrow, flat to concave-outward, posteriorly steeply downsloping to vertical, in posterior view transversely broadly arched. Prosopon smooth; on internal mould pleural ribs finely punctate.

Remarks. Paraplethopeltis seelyi was originally described by Whitfield (1889a, pages 62-63; Plate 13, figures 8-14) from 'the lower six or eight feet of the Calciferous sandrock as exposed about one and a half miles north of Beekmantown Station, on the Delaware and Hudson Railroad, three miles north of Plattsburgh, N.Y.' (Whitfield, 1889a, pages 42, 63). The collection locality, known as the 'Kirby Ledge', is an old quarry, small and overgrown, which occurs in the lower 40 ft. (12 m) limestone unit of the Fort Ann Formation (Dr. R.H. Flower, written communication, 1978). Whitfield (1889a, page 63) reports that *P. seelyi* probably also occurs at Comstock, Washington County, New York.

P. seelyi differs from the type species *P. obesa* Bridge and Cloud, 1947 in having a well defined anterior border, faint eye ridges, and only four axial rings (including the terminal ring) in the pygidium. In these respects, *P. seelyi* closely resembles *P. genacurvis* Hintze (1953; Plate VII, figures 1-5) and *P. genarectus* Hintze (1953; Plate 7, figures 6-9). However, pygidia of the latter two species (Berg and Ross, 1959) have narrower, more conical axes and well developed interpleural furrows as well as pleural furrows. *P. seelyi* has a straight-sided glabella in contrast to the convex-sided glabellas of *P. genacurvis* and *P. genarectus* and has shorter, stubbier genal spines.

Raymond (1913, page 61) and Boyce (1979a, page 8; 1979b) assigned *P. seelyi* to *P. cordai* (Billings, 1860, page 321; Figure 26). However, subsequent examination of the syntype

cranidium of *P. cordai* (GSC 836c) from Levis, Quebec (Plate 17, figures 1-4) shows that the strongly convex anterior border, the much wider and deeper preglabellar, axial, occipital and posterior border furrows, the lack of eye ridges, the narrower palpebral areas and the smaller palpebral lobes readily distinguish *P. cordai* from *P. seelyi*.

The convex-sided glabellas of *P. genacurvis* Hintze, 1953, *P. genarectus* Hintze, 1953, *Paraplethopeltis* sp. E (Ross, 1951 = *Hystricurus?* sp. E Ross, 1951), *Paraplethopeltis* sp. (Ross, 1951 = *Pachycranium?* Ross, 1951), *Paraplethopeltis* sp. aff. *P. genacurvis* Hintze (Berg and Ross, 1959) and *P. nudus* (Poulsen, 1937) readily distinguish them from *P. seelyi*.

Paraplethopeltis seelyi (Whitfield) records evolutionary trends, which eventually culminated in the bathyurid genus *Bolbocephalus* Whitfield, 1890. These trends are:

1) increased convexity of cranidium and pygidium,
2) straighter and more parallel-sided glabella, narrower preglabellar field and shorter anterior border,
3) glabella increasingly overhangs preglabellar field,
4) shorter, stubbier genal spines,
5) progressive effacement and decreased segmentation of axial rings and pleural ribs in pygidium,
6) progressively less distinct posterior border, and
7) transverse arching of posterior border.

Compare *Paraplethopeltis seelyi* (Whitfield) (Plate 17, figures 5-8; Plate 18, figures 1-8; Plate 19, figures 3-8; Plate 20, figures 1-5) to *Bolbocephalus jeffersonensis* Cullison (1944, pages 77-78; Plate XXXIV, figures 28, 29), currently the earliest known species of *Bolbocephalus*.

Genus nov. A

Type species. Gen. nov. A sp. nov. A from the Lower member of the Boat Harbour Formation (St. George Group) at Boat Harbour, western Newfoundland (here designated).

Diagnosis. Cranidium highly convex. Glabella weakly defined, wide, elliptical to subcircular. Anterior border straight to convex-forward, narrow, convex-upward. Posterior border narrow, convex-upward.

Assigned species. The only other species assigned to Gen. nov. A is Undetermined genus and species B of Ross (1951, pages 121-122; Plate 28, figures 16, 20, 25-28) from Zone F in the Garden City Formation of northeastern Utah and from Zone E in the Fillmore Formation (Pogonip Group) at Ibex, western Utah (= the unassigned cranidia of Terrell, 1973; Plate 3, figures 8, 11).

Remarks. Despite the numerous cranidia, this apparently new genus and species is not named because of the lack of pygidia.

Gen. nov. A most closely resembles *Parahystricurus* Ross, 1951 in size, shape and convexity. However, there are two important differences. Firstly, the glabella of Gen. nov. A is rounder than that of *Parahystricurus*, which is more bullet-shaped. Secondly, Gen. nov. A has a smooth prosopon; that of *Parahystricurus* consists of pustules and/or tubercules.

Gen. nov. A sp. nov. A
Plate 20, figures 6-9

1979a cf. genus and species undetermined Ross; Boyce, page 8.
1979b cf. undet. gen. et sp. B Ross; Boyce.
1983b *Magnusnasus proprius* gen. et sp. nov. Boyce, pages 115-118; Plate 9, figures 1-3.

Diagnosis: Glabella relatively well defined; occipital ring distinct. Distinct eye ridges. Preglabellar field narrow.

Stratigraphic range. Lower member of the Boat Harbour Formation, 45.06 to 66.21 m above the base of the Boat Harbour composite section.

Material. Twenty-nine (29) cranidia.

Description. Glabella elliptical, highly convex, transversely moderately vaulted, convex-sided, anteriorly tapering and abruptly rounded; it extends almost six-sevenths total cranidial length. Occipital ring small, subtriangular. Preglabellar and axial furrows weakly defined, narrow, shallow; occipital furrow well defined, wide, deep, convex-forward. Lateral glabellar furrows not developed. Median glabellar tubercule present. Preglabellar field narrow, about one-fourteenth total cranidial sagittal length, convex, anteriorly steeply downsloping. Anterior border furrow distinct, narrow, shallow, broadly convex-forward. Anterior border extremely narrow, less than one-eighth total cranidial sagittal length, convex, of constant width, and flat in anterior view. Anterior fixigenal areas wide, convex, anteriorly steeply downsloping. Anterior portions of facial suture parallel to weakly divergent. Palpebral fixigenal areas the same width as anterior fixigenal areas, abaxially and exsagittally convex and steeply downsloping and traversed by extremely narrow and faint yet distinct ocular ridges. Palpebral lobes small, short–exsagittal length about three-tenths to one-third sagittal glabellar length, wide. Palpebral furrow distinct, wide, shallow. Line through centres of palpebral lobes crosses glabellar sagittal line at about one-half glabellar length from posterior edge of occipital ring. Posterior fixigenal areas incompletely preserved, at least as wide as anterior and palpebral fixigenal areas. Posterior border furrow distinct, wide, shallow. Prosopon smooth.

Hypostoma, librigenae, thorax and pygidium unknown.

Remarks. The less distinct, straighter, narrower anterior border, the narrower preglabellar area, the better defined, more convex glabella, the faint ocular ridges, and the more distinct, wider occipital and posterior border furrows readily distinguish Gen. nov. A sp. nov. A from Undetermined genus and species B of Ross (1951).

Genus nov. B

Type species. Jeffersonia mediacrista Cullison, 1944 from the Rich Fountain Formation (Jefferson City Group) of Missouri–Northern Arkansas (here designated).

Diagnosis. Glabella convex, straight- and parallel-sided, subrectangular, anteriorly gently rounded. Occipital ring sagittally narrow, subrectangular. Preglabellar, occipital and axial furrows well defined. Fixigenae narrow, palpebral area relatively large, low, located posterior to glabellar midpoint. Facial suture extends directly forward from palpebral lobe almost to anterior margin, adaxially curving where it intersects anterior border. Anterior border narrow, convex, abaxially tapering. Pygidium convex, semicircular. Axial lobe weakly convex, posteriorly tapering and abruptly rounded. Five axial rings including terminal ring. Four pairs of pleural and interpleural furrows. Posterior border poorly defined, relatively wide. Prosopon smooth.

Assigned species. Jeffersonia mediacrista Cullison (Plate 21, figures 1-4) and Gen nov. B sp. nov. A (Plate 21, figures 5-8) are the only two species currently recognized as belonging to Gen. nov. B.

Remarks. Gen. nov. B most closely resembles *Paraplethopeltis* Bridge and Cloud, 1947 and *Peltabellia* Whittington, 1953. The differences are discussed below.

The glabella of Gen. nov. B is parallel-sided whereas that of *Paraplethopeltis* is anteriorly tapering.

The cranidial anterior border of Gen. nov. B is less distinct, narrower and less convex than that of *Peltabellia*. In addition, the glabella of Gen. nov. B is anteriorly gently rounded whereas that of *Peltabellia* is abruptly rounded.

Gen. nov. B is less convex and more effaced than both *Paraplethopeltis* and *Peltabellia;* in particular, the pygidial posterior border of Gen. nov. B is less distinct.

Gen. nov. B sp. nov. A
Plate 21, figures 5-8

1979a cf. *'Jeffersonia' mediacrista* Cullison; Boyce, page 8.
1979b aff. *'Jeffersonia' mediacrista* Cullison; Boyce.
1983b *Parapeltabellia boatharbourensis* sp. nov. Boyce, page 150-151; Plate 12, figure 8; Plate 13, figures 2, 4.

Diagnosis. Lateral glabellar furrows not developed. Anterior border faintly defined. Palpebral lobes relatively small, narrow, crescentic.

Stratigraphic range. Lower member of Boat Harbour Formation, 59.31 m above the base of the Boat Harbour composite section.

Material. One (1) cranidium, NFM F-155.

Description. Glabella convex, transversely broadly vaulted, straight- and parallel-sided, subrectangular, anteriorly gently rounded, with faint median longitudinal ridge; it extends about nine-tenths total cranidial length. Occipital ring sagittally narrow, subrectangular. Preglabellar, occipital and axial furrows well defined. Lateral glabellar furrows not developed. Preglabellar field narrow, convex, anteriorly steeply downsloping, about one-twentieth total cranidial length. Anterior border furrow weak. Anterior border faintly defined, narrow, weakly convex, abaxially tapering, in anterior view horizontal. Anterior fixigenal areas narrow, convex, anteriorly steeply downsloping. Anterior portions of facial suture extend directly forward from palpebral lobes almost to anterior margin, adaxially curving where they intersect anterior border. Palpebral fixigenal areas relatively large, about twice width of anterior fixigenal areas, low, adaxially gently downsloping, exsagittally anteriorly gently downsloping, located just behind glabellar midpoint. Palpebral lobes relatively small, narrow crescentic–exsagittal length about two-fifths sagittal glabellar length, narrow, semicircular. Palpebral furrow distinct. Line through centres of palpebral lobes crosses glabellar sagittal line at about one-half glabellar length from posterior edge of occipital ring. Posterior fixigenal areas not preserved. Prosopon smooth.

Hypostoma, librigenae, thorax and pygidium unknown.

Superfamily BATHYURACEA Walcott, 1886
Family BATHYURIDAE Walcott, 1886
Subfamily BATHYURINAE Walcott, 1886
Genus *Bolbocephalus* Whitfield, 1890

Type species. Bathyurus seelyi Whitfield, 1886, *not Bathyurus seelyi* Whitfield, 1889a, from the Fort Cassin Formation (Beekmantown Group) at Fort Cassin, New York.

Diagnosis. See Whittington *in* Moore (1959, pages O376-O377).

Bolbocephalus convexus (Billings, 1865)
Plate 22, figures 1-8

1865 *Dolichometopus? convexus* (n. sp.) Billings, page 269; Figure 253.
1924 *Gignopeltis convexa* (Billings); Raymond, page 455.
1925 *'Dolichometopus' convexus* (Billings); Raymond, page 164.
1937 *Bolbocephalus groenlandicus* n. sp. Poulsen, pages 48,49; Plate 5, figures 9-13.
1978 *Gignopeltis convexus* (Billings); Ludvigsen, page 76; Plate 1, figure 5.
1979a *Gignopeltis convexus* (Billings); Ludvigsen, page 35; Figure 19E.
1979b *Bolbocephalus convexus* (Billings); Ludvigsen, page 861; Plate 1, figures 5, 6.
1979a *Bolbocephalus convexus* (Billings); Fortey, pages 78-80; Plate 26, figures 1-10; Plate 28, figures 9, 10.
1983 *Bolbocephalus convexus* (Billings); Boyce *in* Stouge and Boyce; Plate 15, figures 9, 10.

1983b *Bolbocephalus convexus* (Billings); Boyce, pages 132-134; Plate 11, figures 3, 4.

Diagnosis. Glabella sagittally relatively short, anteriorly rapidly expanding, in dorso-ventral plane highly convex. Pygidium generally effaced, interpleural furrows almost obsolete, posterior border not developed. Diagnosis modified from Fortey (1979a, page 78).

Stratigraphic range. Barbace Cove Member of the Boat Harbour Formation and lower limestone sequence of the Catoche Formation, 72.48 to 93.60 m above the base of the Boat Harbour composite section; lower limestone sequence of the Catoche Formation, 0.29 to 18.55 m above the base of the Cape Norman section.

Material. Nineteen (19) cranidia; thirty-one (31) librigenae; fifty-seven (57) pygidia.

Holotype. Pygidium, GSC 718 from the Catoche Formation on Port aux Choix Peninsula, western Newfoundland (the original of Billings, 1865; Figure 253, by monotypy).

Remarks. As Fortey (1979a) has already provided a detailed description of *B. convexus*, it is not repeated here.

Fortey (1979a, page 80) distinguished *Bolbocephalus groenlandicus* Poulsen, 1937 from *B. convexus* on the basis of more distinct interpleural furrows on the pygidium and dense, rather than scattered punctation on the internal mould. However, the definition of the interpleural furrows in *B. convexus* is variable; dense punctation also occurs. Consequently *B. groenlandicus* is regarded as a junior subjective synonym.

Fortey (1979a, page 80) suggested that the more convex, effaced *Bolbocephalus* species would prove to be characteristic of faunas younger than Ross–Hintze Zones G_1 and G_2, but the opposite is more probably true. The youngest species of *Bolbocephalus* found in western Newfoundland, *Bolbocephalus kindlei* sp. nov., is a strongly furrowed form, conspecific with genus et sp. ind. Poulsen, 1937 and unassigned pygidium 7 of Young (1973; Plate 6, figures 14, 15) from Zone H in Utah. It occurs widely in the Catoche Formation in western Newfoundland, associated with the Zone H species *Benthamaspis gibberula* (Billings).

Bolbocephalus stevensi sp. nov.
Plate 23, figures 1-8; Plate 24, figures 1-10

1967 *Hystricurus* sp. 2 (in part) Lees, pages 39, 78-79; Plate 12, figure 12.
1978 *Bolbocephalus* sp. (in part); Boyce, page 83.
1979a *Bolbocephalus* cf. *B. seelyi* Whitfield (in part); Boyce, page 8.
1979b *Bolbocephalus* cf. *B. seelyi* Whitfield (in part); Boyce.
1983a *Bolbocephalus* sp. 1, Boyce, page 12.

Diagnosis. Glabella sagittally relatively long, almost parallel-sided, anteriorly only slightly expanding. Pygidium with posterior border well defined, relatively narrow. Axial lobe highly convex, posteriorly tapering and abruptly rounded; four well defined axial rings excluding terminal ring. Two anterior pairs of interpleural furrows incomplete, almost nonexistent. Four pairs of pleural furrows well defined, deep.

Etymology. For Dr. R.K. Stevens (Memorial University of Newfoundland), who originally collected specimens of the species.

Stratigraphic range. Barbace Cove Member of the Boat Harbour Formation, 74.34 to 84.56 m above the base of the Boat Harbour composite section.

Material. Six (6) cranidia; twenty-seven (27) pygidia.

Holotype. Pygidium, NFM F-149, from BH-95 in the Barbace Cove Member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated).

Paratypes. Cranidium, NFM F-148, from BH-69; pygidium, NFM F-150, from BH-59; pygidium, NFM F-151, from BH-87; all in the Barbace Cove Member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated).

Description. Glabella highly convex, transversely moderately vaulted, sagittally relatively long, almost straight- and parallel-sided, anteriorly only slightly expanding and abruptly rounded, forward protruding; it overhangs anterior border. Forward glabellar outline broadly semicircular. Occipital ring sagittally relatively wide, rectangular. Preglabellar, occipital and axial furrows well defined, narrow, deep. Lateral glabellar furrows not developed. Preglabellar field and anterior border not preserved on cranidium illustrated (Plate 23, figures 1-4). Anterior fixigenal areas narrow, flat to weakly convex, anteriorly steeply downsloping. Palpebral fixigenal areas about twice the width of anterior fixigenal areas, abaxially horizontal, exsagittally anteriorly very gently downsloping. Palpebral lobes relatively large (for *Bolbocephalus*)–exsagittal length about one-third to two-fifths sagittal glabellar length, wide, crescentic. Palpebral furrow distinct, narrow, deep. Line through centres of palpebral lobes crosses glabellar sagittal line at one-half glabellar length from posterior edge of occipital ring. Posterior fixigenal areas weakly convex, posteriorly gently downsloping. Posterior border furrow distinct, narrow, deep. Prosopon of fine granules. Internal mould finely punctate except for palpebral lobes.

Hypostoma, librigena and thorax unknown.

Pygidium highly convex, semielliptical, length about one-half maximum width at posterior end of articulating facets. Axial lobe strongly convex, cylindro-conical, transversely arched, posteriorly gently tapering and abruptly rounded; it extends about four-fifths to five-sixths total pygidial length.

Four well defined axial rings of even sagittal width and terminal ring with faint pair of tubercules at its posterior end (representing muscle insertion areas—visible on internal mould only). Postaxial area moderately steep, flat, posteriorly downsloping. Axial furrows distinct, deep, narrow. Four pairs of pleural furrows deeper, more distinct; they slope backward posteriorly and stop at posterior border. Posterior border relatively narrow, flat, posteriorly moderately steeply downsloping. Two anterior pairs of interpleural furrows very shallow, incomplete, almost nonexistent; interpleural furrows start just ahead of posterior border furrow and slope backward posteriorly, stopping at posterior margin. Posterior border furrow indistinct. Prosopon smooth. Internal mould finely punctate.

Remarks. The relatively long, nearly parallel-sided, only slightly anteriorly expanding glabella and the relatively large palpebral lobes of the cranidium and the strongly convex, cylindro-conical axial lobe with four well defined axial rings, the two anterior pairs of incomplete, almost nonexistent interpleural furrows and the four pairs of well defined, deep pleural furrows of the pygidium readily distinguish *B. stevensi* from all other presently known species of *Bolbocephalus*. The morphologically closest species *B. jeffersonensis* Cullison (1944; Plate XXXIV, figures 28, 29) has a relatively short, essentially straighter- and more parallel-sided glabella compared to *B. stevensi*. In addition, the pygidial axial lobe of *B. jeffersonensis* contains only three clearly defined axial rings compared to the four present in *B. stevensi*. The type species *B. seelyi* (Whitfield) (see Whittington, 1953; Figure 2; Plate 66, figures 1-10, 12-14, 17, 21, 22) differs from *B. stevensi* in that the glabella is more convex and anteriorly expanding, and the pygidium has extremely strongly developed interpleural as well as pleural furrows. The cranidia of *Bolbocephalus stevensi* sp. nov. and *Hystricurus* sp. 2 of Lees (1967) are synonymized because both have a prosopon of fine granules.

Bolbocephalus kindlei sp. nov.
Plate 25, figures 1-8; Plate 26, figures 1-4

1937 Genus et sp. ind. (trilobite) Poulsen, page 58; Plate 8, figure 2.
1973 Unassigned pygidium 7 Young, page 110; Plate 6, figures 14, 15.
1979a *Bolbocephalus* cf. *B. seelyi* Whitfield (in part); Boyce, page 8.
1979b *Bolbocephalus* cf. *B. seelyi* Whitfield (in part); Boyce.
1983a *Bolbocephalus* sp. nov. 2 Boyce, page 12.
1986 *Bolbocephalus* sp. nov. Boyce, pages 164-167; Plate 1, figures 1-6.

Diagnosis. Terminal axial ring posteriorly truncate. Four pairs of pygidial interpleural furrows extend to posterior margin. Prosopon of fine granules.

Etymology. For Dr. C.H. Kindle, pioneering western Newfoundland paleontologist.

Stratigraphic range. Lower limestone sequence of the Catoche Formation, 1.34 to at least 12.13 m above the base of the Cape Norman section.

Material. Ten (10) pygidia.

Holotype. Pygidium, NFM F-209, from the lower limestone sequence of the Catoche Formation at Marie Cove, southeast of Cape Norman (here designated).

Paratype. Pygidium, MMH 3714, from the Cape Weber Formation on the south coast of Ella Island, east Greenland (the original of Poulsen, 1937; Plate 8, figure 2—here designated).

Description. Cranidium, hypostoma, librigenae and thorax unknown.

Pygidium highly convex, semielliptical, length about four-sevenths to three-fifths maximum width at posterior end of articulating facets. Axial lobe moderately convex, transversely moderately arched, posteriorly gently tapering and abruptly truncated. It extends about seven-tenths to three-quarters total pygidial length. Five well defined axial rings (including terminal ring) of posteriorly decreasing sagittal width. Postaxial area steep, weakly convex, posteriorly downsloping. Axial ring furrows distinct, shallow, narrow; axial, pleural and interpleural furrows more distinct, deeper, wider. Four pairs of pleural furrows; they curve progressively backward posteriorly and stop at posterior border. Four pairs of interpleural furrows; they curve progressively backward and stop at posterior margin, except in very small specimens where they are poorly developed. Posterior border poorly defined (except in large specimens), wide, weakly convex, posteriorly steeply downsloping, in posterior view transversely abruptly arched postaxially. Prosopon of fine granules.

Remarks. The pygidia of *Bolbocephalus kindlei* most closely resemble those of the type species, *Bolbocephalus seelyi* (Whitfield). However, the terminal axial ring of *B. seelyi* is posteriorly abruptly rounded rather than posteriorly abruptly truncate, as in *B. kindlei*. Furthermore, in *B. seelyi* only the most anterior pair of interpleural furrows reaches the posterior margin versus all four pairs in *B. kindlei*. Compare Plate 25, figures 1-8; Plate 26, figures 1-4 with Whitfield (1886; Plate 33, figure 16), Whitfield (1890; Plate 3, figure 7) and Whittington (1953; Figure 2C; Plate 66, figures 14, 17, 22).

Genus *Catochia* Fortey, 1979a

Type species. Catochia ornata Fortey, 1979a, from the Catoche Formation (St. George Group) at Catoche Point, Port au Choix Peninsula, western Newfoundland.

Diagnosis. See Fortey (1979a, page 80).

Catochia ornata Fortey, 1979a
Plate 26, figures 5,6

1979a *Catochia ornata* sp. nov. Fortey, pages 74, 75, 81-84; Figure 12B; Plate 27, figures 1-12.

Diagnosis. See Fortey (1979a, page 81).

Stratigraphic range. Lower limestone sequence of the Catoche Formation, 90.66 to 93.60 m above the base of the Boat Harbour composite section; lower limestone sequence of the Catoche Formation, 1.34 to 19.76 m above the base of the Cape Norman section.

Material. Nine (9) cranidia; thirteen (13) librigenae; one (1) pygidium.

Holotype. Cranidium, GSC 56827, from the Catoche Formation on Port au Choix Peninsula, western Newfoundland (Fortey, 1979a, by monotypy).

Paratypes. Cranidia, GSC 56828, GSC 56829; librigena, GSC 56832; thoracic segment, GSC 56888; pygidia, GSC 56830, GSC 56831; all from the Catoche Formation on Port au Choix Peninsula, western Newfoundland (Fortey, 1979a, by monotypy).

Remarks. As Fortey (1979a) has already provided a detailed description of *C. ornata*, it is not repeated here.

Genus *Jeffersonia* Poulsen, 1927

Type species. Jeffersonia exterminata Poulsen, 1927, from the Nunatami Formation at Nunatami, on the south coast of Washington Land, northwest Greenland.

Diagnosis. Pygidium moderately convex, slightly wider than long. Axial lobe strongly convex, conical. Five axial rings, including terminal ring; posterior two weakly defined. Axial furrow strongly impressed, narrow. Posterior border broad, slightly concave. Posterior margin almost evenly rounded. Prosopon of fine granules or tubercules. Diagnosis modified from Poulsen (1927, page 303).

Remarks: Poulsen (1927, page 303) defined the new species *exterminata* on two pygidia and attributed it to *Jeffersonia* of Ulrich, a close associate, on the assumption that Ulrich was about to publish his manuscript. However, Ulrich never published his generic diagnosis, so *Jeffersonia exterminata* Poulsen 1927, became the type species by monotypy (Cullison, 1944, page 70).

Cullison (1944) attributed nine new species to *Jeffersonia*. Whittington (1953, page 662) doubted that all these species were congeneric and suggested that the name *Jeffersonia* ought to be used solely for the type species.

Poulsen (1937, page 51) erected the genus *Bathyurina*. The type species *Bathyurina megalops* Poulsen (1937, page 52; Plate 6, figures 14, 15; Plate 7, figure 1) was defined on two cranidia from the Cape Weber Formation at Mt. Gunvor, east Greenland. Fortey and Bruton (1973) evidently were able to associate pygidia with cranidia of *Bathyurina;* they reported the presence of *Bathyurina* cf. *timon* (Billings). *Bathyurina timon* (Billings, 1865, page 261; Figure 244) was previously known from pygidia only.

Fortey (1979a) redescribed *B. timon* and illustrated its pygidia and cranidia from the Catoche Formation on Port au Choix Peninsula in western Newfoundland.

The pygidia of *B. timon* (Billings) and *J. exterminata* are similar in that:

1) the pygidia are wider than longer. The pygidium of *J. exterminata* has a length/width ratio of 0.88 (Poulsen, 1927; Plate 20, figure 28). The pygidium of *B. timon* illustrated by Fortey (1979a; Plate 25, figure 3—the original of Billings, 1865; Figure 244) has a length/width ratio of 0.78;
2) the posterior margins of both pygidia are almost evenly rounded;
3) the pygidial borders of both species are broad and flat or slightly concave-upward;
4) the pygidial axial lobes of both species are strongly convex, conical and divided into five axial rings (including the terminal ring) of which only the anterior three are well defined; and
5) the pygidial prosopon consists of granules or tubercules.

On the basis of the above morphological similarities and the fact that *Jeffersonia* Poulsen, 1927 was defined ten years before *Bathyurina* Poulsen, 1937, *B. timon* is assigned to *Jeffersonia*.

Bathyurina will probably prove to be a junior synonym of *Jeffersonia* because presently known species can be assigned to either genus depending on whether cranidia or pygidia are used in the assignment. Because of this, it is further recommended that the name *Bathyurina* be used solely for the type species. However, until cranidia and pygidia are assigned to *Jeffersonia exterminata* and *Bathyurina megalops*, respectively, the congenericity of the two species will remain unproven.

Jeffersonia angustimarginata sp. nov.
Plate 26, figures 7,8; Plate 27, figures 1-10; Plate 28, figures 1-3

1946 Genus et sp. indet. II (in part) Poulsen, page 330, Plate XXIII, figure 10 only.
1967 *Hystricurus* sp. 2 (in part) Lees, pages 39, 78-79; Plate 12, figure 15.
1978 *'Bathyurus' timon* Billings; Boyce, page 83.
1979a *Bathyurina timon* (Billings) (in part); Boyce, page 8.
1979a *Bathyurina timon* (Billings); Fortey, pages 76-78; Plate 25, figure 10 only.
1979a *Bathyurina* sp. indet. Fortey, page 78; Plate 28, figures 8, 10, 11.
1979b *Bathyurina timon* (Billings) (in part); Boyce

1983a *Bathyurina* sp. nov. Boyce, pages 12, 13.
1983 *Bathyurina* sp. Boyce *in* Stouge and Boyce; Plate 13, figure 4.
1986 *Jeffersonia timon* (Billings); Fortey, page 18; Plate 1, figure 6.

Diagnosis: Pygidium strongly convex. Axial lobe with generally four well defined axial rings. Four pairs of deep interpleural furrows. Postaxial area steep (almost vertical) posteriorly downsloping. Posterior border smooth, narrow, flat to slightly concave-upward, moderately downsloping. Prosopon of fine granules or tubercules.

Etymology. From the Latin *angustus* narrow + *marginis* border + *ata* (feminine), referring to the characteristic narrow border of the pygidium.

Stratigraphic range. Barbace Cove Member of the Boat Harbour Formation and lower limestone sequence of the Catoche Formation, 71.80 to 93.60 m above the base of the Boat Harbour composite section; lower limestone sequence of the Catoche Formation, 0.29 to 20.58 m above the base of the Cape Norman section.

Material. Twenty-eight (28) cranidia; thirty-seven (37) librigenae; forty-five (45) pygidia.

Holotype. Pygidium, NFM F-87, from BH-101 in the lower limestone sequence of the Catoche Formation at Boat Harbour, western Newfoundland (here designated).

Paratypes. Cranidium, NFM F-152, from BH-40 in the Barbace Cove Member of the Boat Harbour Formation at Boat Harbour, western Newfoundland; cranidium, NFM F-153, from BH-112 in the lower limestone sequence of the Catoche Formation at Boat Harbour, western Newfoundland; librigena, NFM F-265, from BH-49 in the Barbace Cove Member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated).

Description. Glabella strongly convex, transversely strongly vaulted, straight- and parallel-sided to anteriorly slightly expanding, anteriorly gently rounded, forward protruding; it overhangs anterior border. Anterior glabellar outline broadly elliptical. Occipital ring sagittally narrow, rectangular. Preglabellar furrow poorly defined, narrow, shallow. Occipital and axial furrows well defined wide, deep. Axial furrows anteriorly less well defined, narrower, shallower. Lateral glabellar furrows not developed. Preglabellar field not developed. Anterior border furrow indistinct. Anterior border narrow, convex; abaxially of constant width; anterior profile immediately in front of glabella is convex-forward, abaxially concave-forward. Anterior and posterior fixigenal areas narrow convex, steeply downsloping. Palpebral fixigenal areas large, high, abaxially upward-sloping. Palpebral lobes large, narrow, semielliptical. Palpebral furrow indistinct, narrow, shallow. Line through centres of palpebral lobes crosses glabellar sagittal line at about one half glabellar length from posterior edge of occipital ring. Prosopon of fine granules or tubercules except for anterior border and palpebral lobes. Tuberculation only faintly reflected on internal moulds, however, internal moulds of glabellar axes display fine, scattered pits.

Librigena with genal field strongly convex. Lateral border furrow distinct, wide, deep. Lateral border highly convex, smooth (internal mould) to terrace-lined (external mould), abaxially widening to posterior margin. Genal spine not preserved. Prosopon of fine granules or tubercules, lateral border also displays fine terrace-ridges.

Hypostoma and thorax unknown.

Pygidium strongly convex, semicircular, length about four-fifths maximum width at posterior end of articulating facets. Axial lobe strongly convex, cylindro-conical, transversely arched, posteriorly gently tapering and abruptly rounded; it extends about seven-eighths to nine-tenths total pygidial length. Four well defined axial rings of posteriorly decreasing sagittal width and distinctiveness and terminal ring. Lateral lobes partially developed on abaxial portions of anterior two rings. Axial furrows well defined, deep. Four pairs of pleural furrows, well defined, deep; they slope backward and stop at posterior border. Posterior border well defined, smooth, narrow, flat to concave-upward. Prosopon of fine granules or tubercules except for posterior border, which displays fine terrace-ridges along posterior margin; internal mould finely punctate except for posterior border.

Remarks. The prosopon of fine granules or tubercules, the axial lobe with four, rather than three, well defined axial rings and the relatively narrow border readily distinguish pygidia of *J. angustimarginata* from those of the stratigraphically later *J. timon*. The pygidium of the type species *J. exterminata* Poulsen (1927; Plate XX, figure 28) is less convex, more effaced and only has three easily recognizable axial rings.

Cullison (1944) described and illustrated nine species of *Jeffersonia* from the Rich Fountain, Theodosia and Cotter formations of Missouri and northern Arkansas. Of these only *J. granosa, J. producta, J. delicatula, J. jenii, Jeffersonia* sp. 1 and *Jeffersonia* sp. 2 fit within the concept of *Jeffersonia*. Of the excluded species, *J. missouriensis* probably represents a new genus—its pygidium lacks pleural ribs and has an extremely wide, convex-upward posterior border rather than a narrow, flat to concave-upward posterior border; *J. mediacrista* is elsewhere *(this study)* designated the type species of Gen. nov. B and *J. crassimarginata* is here assigned to *Peltabellia*. With respect to the other Cullison species included in *Jeffersonia, Jeffersonia* sp. 1 and *Jeffersonia* sp. 2 are regarded as conspecific. The two species, which are represented by one pygidia each, are identical except for a small difference in longitudinal profile; this is probably due to their slight size difference (compare Cullison, 1944; Plate XXXV, figures 7, 8 to figures 9, 10). Of the Cullison species, *J. jenii* Cullison (1944; Plate XXXV, figures 17-22) most closely resembles *J. angustimarginata*. The distinguishing difference is that the pygidial border of *J. jenii* is much narrower.

Poulsen (1946; Plate XXIII, figure 10) illustrated an incomplete pygidium from the Canyon Elv Formation (Peel and Cowie, 1979) at Scoresby Bay, Ellesmere Island, which is assigned to *J. angustimarginata* as it possesses the characteristic four well defined axial rings and narrow posterior border. Poulsen (1946; Plate XXIII, figures 6-9) also illustrated a cranidium, librigena, and two flattened pygidia from other beds exposed at Cape Steven, southwest of Scoresby Bay and north of Bache Peninsula. This he included in the same species as the Scoresby Bay pygidium. However, the Cape Steven species is regarded as a different, possibly new species of *Jeffersonia* as its pygidium only has three, rather than four, well defined axial rings and a wide, rather than narrow, posterior border.

The pygidium illustrated by Lees (1967; Plate 12, figure 15) has the four well defined axial rings and narrow posterior border characteristic of *Jeffersonia angustimarginata* sp. nov., and it is assigned to that species.

Bathyurina sp. indet. of Fortey (1979a, page 78; Plate 28, figures 8, 10, 11) is here assigned to *J. angustimarginata* as its pygidium has the characteristically developed four well defined axial rings and narrow posterior border.

Fortey (1979a; Plate 25, figure 10) illustrated another pygidium with a narrow posterior border but assigned it to *Bathyurina timon* (Billings). Despite its having only three well defined axial rings, because of the narrow border, it is assigned to *Jeffersonia angustimarginata* sp. nov.

Fortey (1986, page 18; Plate 1, figure 6) described and illustrated an incomplete pygidium from the Wandel Valley Formation (Christie and Peel, 1977) of eastern north Greenland. This he assigned to *Jeffersonia timon* (Billings). However, the posterior border is much narrower than that of *J. timon* (see Fortey, 1979a; Plate 25, figure 3) and it is more like that of *Jeffersonia angustimarginata* sp. nov.

Jeffersonia timon (Billings, 1865)
Not figured

1865 *Bathyurus timon* (n. sp.) Billings, page 261; Figure 244.
1925 *Petigurus timon* (Billings); Raymond, page 164.
1969 *'Bathyurus' timon* Billings; Whittington and Kindle, page 658.
1978 *'Bathyurus' timon* Billings; Boyce, page 81.
1979a *Bathyurina timon* (Billings) (in part); Boyce, page 8.
1979a *Bathyurina timon* (Billings); Fortey, pages 76-78; Figure 12E; Plate 25, figures 1-10.
1979b *Bathyurina timon* (Billings) (in part); Boyce.
1983b *Jeffersonia timon* (Billings); Boyce, pages 145-146.

Diagnosis. Lateral lobes on occipital ring. Pygidium of moderate convexity. Axial lobe with three well defined axial rings. Posterior border broad, flat or slightly downsloping; median acumination lacking. Prosopon of coarse tubercules except for almost smooth posterior border; postaxially prosopon of fine tubercules. Diagnosis modified and expanded from Fortey (1979a, page 76).

Stratigraphic range. Lower limestone sequence of the Catoche Formation, 1.78 to 21.06 m above the base of the Cape Norman section.

Material. One (1) cephalon; sixty-six (66) cranidia; ninety-one (91) librigenae; forty-three (43) pygidia.

Holotype. Pygidium, GSC 636, from the Catoche Formation on Port au Choix Peninsula (the original of Billings, 1865; Figure 244—by monotypy).

Remarks. As Fortey (1979a) has already provided a detailed description of *J. timon*, it is not repeated here.

Genus *Peltabellia* Whittington, 1953

Type species. Jeffersonia peltabella Ross, 1951, from the Garden City Formation of northeastern Utah.

Diagnosis. Cephalon strongly convex. Glabella straight- and parallel-sided, anteriorly abruptly rounded to pointed. Lateral glabellar furrows not developed. Anterior border extremely narrow and convex, of constant width. Anterior sections of facial suture slightly divergent. Genal spines short. Pygidium with posterior border broad, smooth, weakly to moderately convex. Prosopon punctate, smooth or tuberculate.

Peltabellia knighti sp. nov.
Plate 28, figures 4-10; Plate 29, figures 1, 2

1967 *Bathyurellus* sp. 1 Lees, pages 27, 39, 78-79; Plate 12, figures 6-8, 10.
1978 *'Peltabellia'* sp. Boyce, page 83.
1979a *Peltabellia* sp. nov. Boyce. page 8.
1979b *Peltabellia* sp. nov. Boyce.
1983 *Peltabellia* sp. nov. Boyce *in* Stouge and Boyce; Plate 16, figures 3-5.

Diagnosis. Glabella anteriorly effaced. Pygidium with two to three axial rings variably defined; only two pleural ribs. Posterior border relatively narrow. Prosopon smooth. Internal mould punctate.

Etymology. For Dr. I. Knight (Geological Survey Branch, Newfoundland Department of Mines and Energy), who originally collected this species and who has done much to unravel the Cambrian—Ordovician lithostratigraphy of western Newfoundland.

Stratigraphic range. Barbace Cove Member of the Boat Harbour Formation, 73.62 to 79.39 m above the base of the Boat Harbour composite section.

Material. Fifty-three (53) cranidia; sixty-seven (67) librigenae; one hundred and fourteen (114) pygidia.

Holotype. Pygidium, NFM F-157 from BH-46 in the Barbace Cove Member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated).

Paratypes. Cranidia, NFM F-112 from BH-46, NFM F-156 from BH-47; librigena, NFM F-113 from BH-46; pygidium, NFM F-114 from BH-46; all in the Barbace Cove Member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated).

Description. Glabella highly convex, transversely strongly vaulted, straight- and parallel-sided, anteriorly abruptly rounded and effaced; it extends about nine-tenths total cranidial length, and overhangs the preglabellar area. Occipital ring sagittally narrow, rectangular, with small occipital node. Preglabellar furrow well defined, narrow, deep, adaxially becomes shallow, indistinct. Axial furrows well defined, wide, deep; occipital furrow narrower. Lateral glabellar furrows not developed. Preglabellar field extremely narrow, convex, steeply anteriorly downsloping, about one-twentieth total sagittal cranidial length. Anterior border furrow distinct, narrow, deep, convex-forward. Anterior border transversely long, extremely narrow and convex, of constant width in dorsal view; transversely broadly arched in anterior view. Anterior fixigenal areas of moderate width, convex, anteriorly steeply downsloping. Palpebral fixigenal areas only slightly wider than anterior fixigenal areas, abaxially horizontal to very gently upsloping, exsagittally anteriorly very gently downsloping. Palpebral lobes relatively large, long–exsagittal length about one-third sagittal glabellar length, wide, convex, semicircular. Palpebral furrow distinct, narrow. On internal mould, palpebral lobe is extremely narrow and convex and palpebral furrow distinct, extremely wide, shallow. Line through centres of palpebral lobes crosses glabellar sagittal line at about one-half glabellar length from posterior edge of occipital ring. Posterior fixigenal areas narrow, convex, posteriorly moderately steeply downsloping. Posterior border furrows distinct, narrow, deep. Posterior border strongly convex. Prosopon smooth. On internal mould, glabella finely punctate.

Hypostoma unknown.

Librigena with genal field highly convex. Lateral border furrow distinct, narrow, deep adjacent to facial suture, abaxially becomes less distinct, wider, shallower to posterior border furrow. Lateral border extremely narrow and convex, abaxially becomes substantially wider and less convex to posterior border. Posterior border furrow distinct, narrow, shallow. Posterior border wide, weakly convex. Genal spine long and narrow, flat to moderately convex. Prosopon smooth.

Thorax unknown.

Pygidium moderately convex, semielliptical, length about one-half to three-fifths maximum width at posterior end of articulating facets. Axial lobe highly convex, transversely strongly arched, posteriorly gently tapering and abruptly rounded; it extends about three-quarters to six-sevenths total pygidial length. Two to three axial rings variably defined, of constant sagittal width. Axial furrows and two pairs of pleural furrows distinct, wide, deep. Interpleural furrows not developed. Only two pairs of pleural ribs; these stop at posterior border. Posterior border weakly defined, relatively narrow, weakly to moderately convex, moderately steeply downsloping, anteriorly narrower than postaxially, in posterior view horizontal. Prosopon smooth. Internal mould finely punctate.

Remarks. Peltabellia knighti most closely resembles *P. crassimarginata* (Cullison, 1944, pages 75, 76; Plate XXXV, figures 13-16) and *P. willistoni* Lochman (1966, page 542; Plate 62, figures 10, 11). However, the pygidia of the latter two species differ from that of *P. knighti* in having four to five axial rings, and three pleural ribs.

The pygidia illustrated by Lees (1967; Plate 12, figures 7,8,10) conform well to the diagnosis of *Peltabellia knighti* sp. nov. and are assigned to that species.

Peltabellia crassimarginata (Cullison, 1944)
Not figured

1944 *Jeffersonia crassimarginata* n. sp. Cullison, pages 75-76; Plate XXXV, figures 13-16.
1986 *Peltabellia* sp. cf. *P. crassimarginata* (Cullison); Boyce, page 163.

Diagnosis. Peltabellia with postaxially flattened pygidial border.

Stratigraphic range. Barbace Cove Member of the Boat Harbour Formation, 75.49 m above the base of the Boat Harbour composite section.

Material. Two (2) pygidia.

Remarks. The Boat Harbour material adds no new information to the concept of this species. As Cullison (1944) provided an adequate description of *P. crassimarginata*, it is not repeated here.

Peltbabellia sp. cf. *P. peltabella* (Ross, 1951)
Plate 29, figures 2-4

1983b *Peltabellia pseudopeltabella* sp. nov. Boyce, pages 155-157; Plate 14, figures 3, 5, *not* figures 2, 4.

Diagnosis. Pygidial axial lobe consists of at least four axial rings of posteriorly decreasing distinctiveness. Posterior border weakly defined, extremely wide, convex. Prosopon smooth. Internal mould finely punctate.

Stratigraphic range. Barbace Cove Member of the Boat Harbour Formation, 76.50 to 77.05 m above the base of the Boat Harbour composite section.

Material. Two (2) pygidia.

Description. Cranidium, hypostoma, librigenae and thorax unknown.

Pygidium moderately convex, semicircular, length about three-quarters maximum width at posterior end of articulating facets (estimated). Axial lobe strongly convex, transversely highly vaulted, cylindro-conical, almost parallel-sided, posteriorly gently tapering and abruptly rounded; it extends about five-eighths total pygidial length. Axial furrows well defined. Pleural furrows narrow, posteriorly becoming less distinct and shallower. Three axial rings of equal (sagittal) width becoming progressively indistinct posteriorly. Axial furrows well defined. Three pairs of pleural ribs, posterior pair almost nonexistent. Interpleural furrows not developed. Posterior border weakly defined—almost indistinct in large individual (Plate 29, figure 3), extremely wide, convex, strongly downsloping. Prosopon smooth. Internal mould smooth except posterior border finely punctate.

Remarks. *Peltabellia* sp. cf. *P. peltabella* most closely resembles *P. sibirica* (Maximova 1955; Plate VIII, figure 6) and the type species *P. peltabella* (Ross, 1951; Plate 17, figures 19, 21). However, the pygidia of the latter species are less effaced and have more posteriorly tapering axial lobes and narrower posterior borders. The prosopon of tubercules, less convex axis, and posteriorly less downsloping and convex posterior border also distinguishes *P. peltabella* from *P.* sp. cf. *P. peltabella*. The much wider posterior border of *P.* sp. cf. *P. peltabella* also readily distinguishes it from *Peltabellia* sp. B (Hintze, 1953; Plate IX, figure 8), *P. knighti* sp. nov. (Plate 28, figures 4-10; Plate 29, figures 1 and 2) and *P. willistoni* Lochman (1966; Plate 62, figures 10, 11).

Genus *Petigurus* Raymond, 1913

Type species. *Bathyurus nero* Billings, 1865, from the Catoche Formation (St. George Group) on Port au Choix Peninsula, western Newfoundland.

Diagnosis. Glabella straight-sided, anteriorly weakly expanding and strongly forward-protruding; it overhangs anterior margin. Posterior fixigenal areas long, narrow. Pygidium subtriangular to semielliptical with five axial rings, including terminal ring, well defined. Four to five pairs of pleural furrows strongly developed. Interpleural furrows variably developed. Prosopon of coarse tubercules.

Petigurus nero (Billings, 1865)
Plate 29, figure 6

1865 *Bathyurus nero* (n. sp.); Billings, pages 260-261; figure 243.
1913 *Petigurus nero* (Billings); Raymond, pages 58-59; Plate 7, figure 8.
1925 *Petigurus nero* (Billings); Raymond, page 164.
1953 *Petigurus nero* (Billings); Whittington, page 658; Figure 3; Plate 66, figures 18-20.
1959 *Petigurus nero* (Billings); Whittington *in* Moore, pages O378, O379; Figures 285, 5a,b.
1979a *Petigurus nero* (Billings); Fortey, pages 84-86; Plate 29, figures 1-12, 15.
1983 *Petigurus nero* (Billings); Boyce *in* Stouge and Boyce; Plate 13, figures 1, 2.
1983b *Petigurus nero* (Billings); Boyce, pages 157-159; Plate 14, figure 6.
1986 *Petigurus nero* (Billings); Fortey, page 19; Plate 2, figures 1,3,4.

Diagnosis. Pygidial interpleural furrows adaxially obsolete. Prosopon of coarse tubercules. Diagnosis modified from Fortey (1979a, page 84).

Stratigraphic range. Barbace Cove Member of the Boat Harbour Formation and lower limestone sequence of the Catoche Formation, 76.85 to 93.60 m above the base of the Boat Harbour composite section; lower limestone sequence of the Catoche Formation, 1.34 to 21.06 m above the base of the Cape Norman section.

Material. Thirty-five (35) cranidia; thirty-eight (38) librigenae; forty-one (41) pygidia.

Lectotype. Internal mould of glabella, GSC 750, from the Catoche Formation (St. George Group) on Port au Choix Peninsula, western Newfoundland (selected by Whittington, 1953, page 658—by monotypy).

Remarks. As Fortey (1979a, pages 84, 86) has already provided a detailed description of *P. nero*, it is not repeated here.

Petigurus sp. nov. A
Plate 29, figure 7

1944 Gen. (?) sp. (?) Cullison, pages 84-85; Plate XXXV, figures 23, 24.
?1953 Undetermined pygidium Hintze, Plate XX, figures 14a, b.
1967 *Hystricurus* sp. 1 Lees, pages 39, 78-79; Plate 12, figures 13, 14
1979a *Petigurus* sp. indet. Fortey, pages 86-87; Plate 29, figures 13, 14.
1983a *Hystricurus* sp. nov. 3, Boyce, pages 12, 13.
1985 *Petigurus* sp. nov. Boyce, page 63, figure 2.
1987 *Petigurus* sp. indet. Williams *et. al.*, page 458, figure 2.

Stratigraphic range. Barbace Cove Member, Boat Harbour Formation to 10 m above the base of the Catoche Formation, Port au Choix.

Material. Forty (40) cranidia; thirty-eight (38) librigenae; twenty-two (22) pygidia.

Remarks. Although this species is represented by an abundance of material at Port au Choix and Eddies Cove

West, it has yet to be studied in detail. Consequently, it is not formally named in this study.

The pygidium of *Petigurus* sp. nov. A is distinctive. The axis comprises four well-defined axial rings and a terminal ring. Four well defined pairs of pleural furrows extend almost to the posterior margin. There are no interpleural furrows.

The undetermined pygidium of Hintze (1953; Plate XX, figures 14a, b) is only tentatively synonymized with *Petigurus* sp. nov. A, because it is difficult to tell from Hintze's photographs whether it has three or four axial rings.

The specimens of *Hystricurus* sp. 1 illustrated by Lees (1967; Plate 12, figures 13, 14) are conspecific with *Petrigurus* sp. nov. A.

Genus *Strigigenalis* Whittington and Ross *in* Whittington, 1953

Type species. Strigigenalis cassinensis Whittington, 1953, from the Fort Cassin Formation (Beekmantown Group) at Fort Cassin, Vermont.

Diagnosis. Cephalon weakly to moderately convex. Glabella straight- and parallel-sided to convex-sided. Lateral glabellar furrows not developed. Anterior border narrow, convex. Pygidium with posterior border broad, smooth, weakly to moderately convex. Posterior spine short to long.

Strigigenalis brevicaudata sp. nov.
Plate 29, figures 8-10; Plate 30, figures 1-10

1979a *Strigigenalis* sp. nov. Boyce, page 8.
1979b *Strigigenalis* sp. nov. Boyce.
1983 *Strigigenalis* sp. nov. Boyce *in* Stouge and Boyce; Plate 16, figure 6.

Diagnosis. Pygidial axial lobe convex-sided, posteriorly tapering and abruptly rounded. At least three axial rings of posteriorly decreasing sagittal width. Posterior spine short, broadly triangular with median carina on internal mould.

Etymology. From the Latin *brevis* short + *cauda* tail + *ata* (feminine), referring to the characteristic short posterior spine.

Stratigraphic range. Barbace Cove Member of the Boat Harbour Formation, 71.80 to 84.56 m above the base of the Boat Harbour measured sequence.

Material. Forty-two (42) cranidia; thirty-four (34) librigenae; fifty-six (56) pygidia.

Holotype. Pygidium, NFM F-163 from BH-67 in the Barbace Cove Member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated).

Paratypes. Cranidium, NFM F-160 from Bed 39 of Section BHS-6; librigena, NFM F-161 from Bed 39 of Section BHS-6; pygidium, NFM F-115 from BH-92; all from the Barbace Cove Member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated).

Description. Glabella highly convex, transversely moderately vaulted, straight- and parallel-sided to slightly convex-sided, anteriorly abruptly rounded; it extends about six-sevenths total cranidial length. Occipital ring sagittally narrow, rectangular. Preglabellar, axial and occipital furrows well defined, narrow, deep. Lateral glabellar furrows not developed. Preglabellar field extremely narrow, convex, anteriorly steeply downsloping, about one-fourteenth total sagittal cranidial length. Anterior border furrow distinct, narrow, deep, convex-forward. Anterior border transversely long, narrow–of constant width, convex, in anterior view transversely broadly arched. Anterior fixigenal areas of moderate width, convex, anteriorly steeply downsloping. Palpebral fixigenal areas only slightly wider than anterior fixigenal areas, abaxially very gently upsloping, exsagittally anteriorly very gently downsloping. Ocular ridges thick, well defined. Palpebral lobes relatively large, long–exsagittal length about one-third sagittal glabellar length, wide, convex, crescentic. Palpebral furrow distinct, narrow. On internal mould, palpebral lobe extremely narrow, convex; palpebral furrow distinct, extremely wide, shallow. Line through centres of palpebral lobes crosses glabellar sagittal line at about one-half glabellar length from posterior edge of occipital ring. Posterior fixigenal areas narrow, convex, posteriorly moderately steeply downsloping. Posterior border furrows distinct, narrow, deep. Posterior border strongly convex. Prosopon smooth.

Hypostoma unknown.

Librigena with genal field moderately convex. Lateral border furrow distinct, narrow, deep adjacent to facial suture, abaxially becomes less distinct, wider, shallower to posterior border furrow. Lateral border narrow, convex, abaxially becomes substantially wider and less convex to posterior border. Posterior border furrow distinct, narrow, shallow. Genal spine relatively long and narrow, flat to moderately convex. Prosopon smooth.

Thorax unknown.

Pygidium weakly to moderately convex, triangular, length about two-thirds to six-sevenths maximum width at posterior end of articulating facets. Axial lobe highly convex, transversely strongly arched, convex-sided, posteriorly gently tapering and abruptly rounded; it extends about three-fifths total pygidial length. At least three axial rings of posteriorly decreasing sagittal width. Axial furrows distinct, narrow, deep. Three pairs of pleural furrows distinct, wide, shallow. One anterior pair of interpleural furrows almost indistinct. Three pairs of pleural ribs, posteriorly progressively less distinct; these stop at posterior border. Posterior border weakly defined, narrow, weakly to moderately convex, moderately steeply downsloping, narrower anteriorly than

postaxially. Posterior spine short, broadly triangular, posteriorly horizontal to gently upsloping; on internal moulds spine carries median carina. Prosopon smooth.

Remarks. Young (1973; Plate 6, figures 16, 19, 22) illustrated two pygidia from Zone H in the Fillmore Formation (Pogonip Group) of western Utah, which are assigned to *Strigigenalis*. These pygidia closely resemble *S. brevicaudata*. However, their straight- to concave-sided axial lobes with only two distinct axial rings, less distinct pleural ribs, relatively wider anterior borders and differently shaped and variably developed posterior spines readily distinguish them from that species. These pygidia ('unassigned pygidia 8 and 11' of Young, 1973) are assigned to *Bathyurellus(?) teretus* Young 1973; Plate 22, figures 5, 8-10, 13, 14). Fortey (1979a, page 92) attributed 'unassigned pygidium 9' of Young (1973; Plate 6, figures 17-20) to this species. However, here it is assigned to *Benthamaspis gibberula* (Billings), based on a comparison with pygidia of *B. gibberula* illustrated by Fortey (1979; Plate 34, figures 8, 10, 11, 13). Fortey (1979a, page 92) referred *Bathyurellus(?) teretus* to *Bathyurellus s.s.* but the size and shape of the anterior border, glabella, occipital ring and palpebral lobe are considered to be more characteristic of *Strigigenalis*.

Strigigenalis caudata (Billings, 1865)
Plate 31, figures 1-8

1865 *Bathyurus caudatus* (n. sp.) Billings, pages 261, 262; Figure 245.
1925 *Goniurus caudatus* (Billings); Raymond, page 164.
1944 *Goniotelus semicircularis* n. sp. Cullison, page 84; Plate XXXV, figures 25-26.
1953 Gen. et sp. ind. (pygidium) Whittington, page 670; Plate 68, figures 30-32.
1967 *Bathyurellus* sp. 2 Lees, pages 27, 39 78-79; Plate 12, figures 4, 5.
1978 *'Bathyurus' caudatus* Billings. Boyce, pages 81, 83.
1979a *Strigigenalis caudata* (Billings); Fortey, pages 74, 75 88-90, figure 12D; Plate 30, figures 1-10.
1983 *Strigigenalis caudata* (Billings); Boyce *in* Stouge and Boyce; Plate 16, figure 7.
1983b *Strigigenalis caudata* (Billings); Boyce, pages 164-165; Plate 15, figures 5, 6; Plate 16, figures 1, 2.

Diagnosis. Glabella anteriorly pointed. Preglabellar field short, downsloping. Anterior border not acuminate medially. Pygidium with posterior spine relatively long, triangular with median carina on internal mould. Prosopon smooth. Diagnosis modified from Fortey (1979a, page 88).

Stratigraphic range. Barbace Cove Member of the Boat Harbour Formation and lower limestone sequence of the Catoche Formation, 83.88 to 93.60 m above the base of the Boat Harbour composite section; lower limestone sequence of the Catoche Formation, 7.72 to 19.76 m above the base of the Cape Norman section.

Material. Eleven (11) cranidia; nine (9) librigena; six (6) pygidia.

Holotype. Pygidium, GSC 635, from the Catoche Formation (St. George Group) on Port au Choix Peninsula, western Newfoundland (the original of Billings, 1865; Figure 245, by monotypy).

Remarks. As Fortey (1979a) has already provided a detailed description of *S. caudata*, it is not repeated here.

Goniotelus semicircularis Cullison (1944; Plate XXXV, figures 25, 26) is synonymized with *Strigigenalis caudata* based on the comparable size and shape of 1) the pygidial axial lobes and 2) the posterior spines of the two species.

The pygidia illustrated by Lees (1967; Plate 12, figures 4,5) easily fit within the concept of *Strigigenalis caudata* (Billings); Lees (1967, page 27) himself commented on the strong resemblance of his specimens to that illustrated by Whittington (1953; Plate 68, figures 30-32).

S. caudata is regarded as the direct sympatric evolutionary descendent of *S. brevicaudata* for the following reasons:

1) The two species strongly resemble each other; the distinguishing difference is the longer posterior spine of *S. caudata*.

2) The overlap of the ranges of the two species is only 0.68 m within the same environment in Bed 39 of Section BHS 6.

Subfamily BATHYURELLINAE Hupé, 1953
Genus *Bathyurellus* Billings, 1865

Type species. Bathyurellus abruptus Billings, 1865, from the Catoche Formation (St. George Group) on Port au Choix Peninsula and Keppel Island, western Newfoundland (designated by Raymond, 1905, page 337).

Diagnosis: Cranidium resembles that of *Punka* Fortey, 1979a but glabella transversely not highly vaulted. Anterior border narrow. Librigenae exsagittally convex. Lateral border narrow, rim-like. Pygidium with pleural fields hardly furrowed behind anterior segment. Posterior border broad, depressed. Diagnosis modified from Fortey (1979a, page 90).

Bathyurellus abruptus Billings, 1865
Not figured

1865 *Bathyurellus abruptus* (n. gen. n. sp.) Billings, pages 263, 264, figures 247, 250.
1905 *Bathyurellus abruptus* Billings; Raymond, page 337.
1925 *Bathyurellus abruptus* Billings; Raymond, pages 71-72, 164; Plate 3, figure 18.
1953 *Bathyurellus abruptus* Billings; Whittington, page 660, Plate 69, figures 26, 27.
1979a *Bathyurellus abruptus* Billings; Fortey, pages 74, 75, 92, 94; figure 12C; Plate 32, figures 1-12.

1983 *Bathyurellus abruptus* Billings; Boyce *in* Stouge and Boyce; Plate 14, figures 6; Plate 15, figures 1, 4.
1983b *Bathyurellus abruptus* Billings; Boyce, pages 166-167.
1986 *Bathyurellus abruptus* Billings; Fortey, pages 19-20; Plate 2, figures 2,6,7.

Diagnosis. Prosopon of dense terrace-lines on preoccipital glabella and over most of librigenae. Pygidium with posterior border postaxially broad, concave-upward. Diagnosis modified from Fortey (1979a, page 92).

Stratigraphic range. Lower limestone sequence of the Catoche Formation, 1.34 to 21.06 m above the base of the Cape Norman section.

Material. Twenty-two (22) cranidia; three (3) hypostomata; fifty-two (52) librigenae; ninety-four (94) pygidia.

Lectotype. Pygidium, GSC 648, from the Catoche Formation on Port au Choix Peninsula, western Newfoundland (selected by Whittington, 1953, page 660, by monotypy).

Remarks. As Fortey (1979a) has already provided a detailed description of *B. abruptus*, it is not repeated here.

Genus *Benthamaspis* Poulsen, 1946

1966 *Oculomagnus* Lochman, pages 541-542 (see Fortey, 1979a, page 100)

Type species. Benthamaspis problematica Poulsen 1946, from the Nunatami Formation(?) at Cape Steven, Ellesmere Island.

Diagnosis. Glabella straight- and parallel-sided to anteriorly gently tapering and broadly rounded. Palpebral lobes long, narrow, crescentic. Cranidial prosopon of convex-forward terrace lines. Pygidium with axial lobe small, straight-sided, posteriorly tapering and abruptly rounded to truncated. Pygidial prosopon consists of convex-forward terrace lines on axial lobe and concave-forward terrace lines on pleural field.

Remarks. Like the bathyurellines *Bathyurellus* Billings, 1865, and *Punka* Fortey, 1979a, *Benthamaspis* has long, narrow, crescentic palpebral lobes with faint palpebral furrows; lateral glabellar furrows are also not developed (see Fortey, 1979a; Plates 31-35). In addition, all three genera have prosopons of fine terrace lines. Cranidia of *Benthamaspis distinctus* Young (1973; Plate 1, figures 11, 12, 15 and 16 only) display anterior borders and preglabellar areas comparable to *Bathyurellus*. Like *Bathyurellus*, *Benthamaspis* has a conical pygidial axial lobe and a distinct anterior pair of pleural furrows. *Bathyurellus* has a distinctive axial notch/groove in the pygidial doublure (see Fortey, 1979a; Plate 32, figure 12), *Punka* has an axial notch in the pygidial doublure also (see Fortey, 1979a; Plate 33, figure 10) as does *Benthamaspis* (see Young, 1973; Plate 6, figure 20).

Because of the above similarities to *Bathyurellus* Billings, 1865 and *Punka* Fortey, 1979a, *Benthamaspis* is assigned to the subfamily Bathyurellinae Hupé, 1953. Dr. S.R. Westrop of Brock University, first suggested the possibility that *Benthamaspis* was a bathyurid rather than a lecanopygid (personal communication, 1986).

Gignopeltis Raymond, 1924, is a problematic monotypic bathyurid genus. The only known species *Gignopeltis rarus* (Billings, 1865) is based solely upon a single, poorly preserved internal mould of a pygidium from the Oxford Formation of southeastern Ontario (Ludvigsen, 1979b).

Billings (1865) originally grouped *Gignopeltis rarus* (Billings) with *Benthamaspis gibberula* (Billings) and *Bolbocephalus convexus* (Billings) and described them together under the generic name *Dolichometopus* ?.

Ludvigsen (1979b) and Fortey (1979a) have suggested that *Gignospeltis* is a (junior) synonym of *Bolbocephalus* Whitfield, 1890. However, *Gignopeltis* may eventually prove to be a senior synonym of *Benthamaspis* as the pygidia of *Gignopeltis rarus* (Billings) and *Benthamaspis hintzei* sp. nov. share the following characters:

1) the axial lobes are posteriorly tapering and abruptly rounded to pointed,
2) at least four axial rings (including terminal ring) are developed, the anteriormost being the best defined, and
3) weak pleural and interpleural furrows are present.

Although cranidia of *Benthamaspis hintzei* are known, *Gignopeltis rarus* cranidia have not yet been found. Consequently, the synonymy of *Gignopeltis* is still undecided.

Benthamaspis hintzei sp. nov.
Plate 32, figures 1-8

1953 Undetermined gen. and sp. B Hintze, page 242; Plate XIII, figure 17 only.
1953 Unassigned pygidium Hintze, Plate XV, figures 18a,b.
1979a *Benthamaspis* cf. *B. conica* Fortey (in part); Boyce, page 8.
1979b *Benthamaspis* sp. nov. (in part); Boyce.
1983a *Benthamaspis* sp. nov. Boyce, pages 12, 13.

Diagnosis. Pygidium with five axial rings (including terminal ring) visible on internal mould. Pleural and interpleural furrows faint.

Etymology. For Dr. L.F. Hintze (Brigham Young University) who originally illustrated examples of this species.

Stratigraphic range. Barbace Cove Member of the Boat Harbour Formation and lower limestone sequence of the

Catoche Formation, 75.59 to 93.60 m above the base of the Boat Harbour composite section.

Material. Three (3) cranidia; seven (7) pygidia.

Holotype. Pygidium, NFM F-175 from BH-110 in the lower limestone sequence of the Catoche Formation at Boat Harbour, western Newfoundland (here designated).

Paratypes. Cranidium, NFM F-173 from BH-101/BH-110; pygidium, NFM F-174 from BH-112; both in the lower limestone sequence of the Catoche Formation at Boat Harbour, western Newfoundland (here designated). Pygidium, NFM F-176 from BH-62 in the Barbace Cove Member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated).

Description. Glabella highly convex, transversely strongly vaulted, straight-sided, anteriorly gently tapering and broadly rounded to slightly truncated. Occipital ring sagittally wide, subrectangular. Preglabellar, axial and occipital furrows distinct, narrow, shallow. Preglabellar and anterior fixigenal areas not preserved. Palpebral fixigenal areas wide, convex, anteriorly and abaxially steeply downsloping. Palpebral lobes poorly defined, long–exsagittal length about six-tenths to two-thirds sagittal glabellar length, narrow, broadly crescentic. Palpebral furrows indistinct. Line through centres of palpebral lobes crosses glabellar sagittal line at about one-half glabellar length from posterior edge of occipital ring. Posterior fixigenal areas small, convex. Posterior border furrow distinct, narrow, shallow. Posterior border short, weakly convex. Glabellar prosopon consists of fine, dense, convex-forward terrace-lines. Fixigenal prosopon smooth.

Hypostoma, librigenae and thorax unknown.

Pygidium convex, semielliptical, length about one-half to three-fifths maximum width at posterior end of articulating facets. Axial lobe transversely strongly arched, posteriorly tapering and abruptly rounded to pointed; it extends one-half to two-thirds total pygidial length. Five axial rings (including terminal ring) of approximately equal sagittal width are observed on internal mould; these are only faintly reflected on external mould. Postaxial area and pleural fields wide, evenly convex, steeply downsloping. Anterior pair of pleural furrows distinct. Anterior pair of interpleural furrows less distinct. Additional pairs of fainter, incomplete pleural and interpleural furrows are also developed. Posterior border not developed. Doublure of constant width, about one-half total pygidial length, parallel to posterior margin; inner dorsal surface flat to concave, steeply downsloping. Pygidial prosopon of fine, dense, convex-forward terrace lines on axial lobe and concave-forward terrace lines parallel to posterior margin on postaxial area, pleural fields and doublure.

Remarks. The pygidium illustrated by Hintze (1953; Plate XV, figures 18a,b) has slightly better defined axial rings than the Newfoundland specimens but agrees closely in most other respects. The cranidium illustrated by Hintze (1953; Plate XIII, figure 17) is assigned to *B. hintzei* because it has a similarly shaped glabella and a well defined occipital ring.

Benthamaspis conica Fortey, 1979a
Not figured

1960 'New genus related to *Strigigenalis* and *Benthamaspis*' Berry; Plate 7, figures 1,3.
1966 *Oculomagnus obreptus* n. gen. n. sp. (in part); Lochman, pages 541-542; Plate 62, figures 1, 2, 4 only.
1979a *Benthamaspis* cf. *B. conica* Fortey (in part); Boyce, page 8.
1979b *Benthamaspis* sp. nov. (in part), Boyce.
1979a *Benthamaspis conica* sp. nov. Fortey, pages 102, 104-105; Plate 35, figures 1-10.
1986 *Benthamaspis conica* Fortey; Fortey, pages 20-21; Plate 1, figures 1,2.

Diagnosis. Benthamaspis species with preglabellar furrow defined. Occipital furrow extending almost to axial furrow. Diagnosis from Fortey (1979a, page 102).

Stratigraphic range. Lower limestone sequence of the Catoche Formation, 7.22 to 18.27 m above the base of the Cape Norman section.

Material. Five (5) cranidia; four (4) pygidia.

Holotype. Cranidium, GSC 56873, from the Catoche Formation on Port au Choix Peninsula, western Newfoundland (Fortey, 1979a, by monotypy).

Paratypes. Cranidia, GSC 56874, GSC 56875; librigena, GSC 56878; pygidia, GSC 56876, GSC 56877; all from the Catoche Formation on Port au Choix Peninsula, western Newfoundland (Fortey, 1979a, by monotypy).

Remarks. As Fortey (1979a) has already provided a detailed description of *B. conica*, it is not repeated here.

Recently, the large paratype pygidium illustrated by Fortey (1979; Plate 35, figures 8, 9–GSC 56876) has been examined by the author. The axial lobe consists of three axial rings and a terminal ring. The axial ring furrows are strongly anteriorly convex. These features readily distinguish *Benthamaspis conica* Fortey from *B. hintzei* sp. nov.

Benthamaspis sp. cf. *B. conica* Fortey, 1979a
Plate 32, figures 9-11

1979a *Benthamaspis* cf. *B. conica* Fortey (in part); Boyce, page 8.
1979b *Benthamaspis* sp. nov. (in part) Boyce.
1983b *Benthamaspis conica* Fortey, 1979a; Boyce, pages 178-179.

Stratigraphic range. Lower limestone sequence of the Catoche Formation, 7.22 to 19.76 m above the base of the Cape Norman section.

Material. Twelve (12) pygidia.

Remarks. The Cape Norman pygidia obtained are poorly preserved. Their axial lobes are more cylindro-conical than those of *Benthamaspis conica* so they are not assigned to that species. Fortey (1979a, page 64) examined material originally collected by Whittington and Kindle from Cape Norman and reported the presence of *Benthamaspis* cf. *B. gibberula.* It is possible that the *Benthamaspis* species reported by Fortey and the author, from here, are one and the same and that they represent a new species. Further collecting is required to settle the matter.

Genus *Grinnellaspis* Poulsen, 1948

Type species. Actinopeltis feildeni Poulsen, 1946, from the Cape Weber Formation at Scoresby Bay, Ellesmere Island.

Remarks. Until recently this genus was represented solely by the type species *Grinnellaspis feildeni* (Poulsen), known only from one pygidium (Poulsen, 1946, pages 324-325; Plate XXII, figures 8, 9). However, *Grinnellaspis newfoundlandensis* sp. nov. *(this study)* is represented by cranidia, librigenae, and pygidia. Based on the new material described below, the generic diagnosis by Rasetti *in* Moore (1959, pages O522, O523; Figure 412 7) has been revised and expanded.

Diagnosis. Glabella straight- and parallel-sided, anteriorly evenly rounded. Preglabellar area wide. Anterior border wide, strongly concave. Pygidium subelliptical to elliptical, flat. Axial lobe conical, short, composed of up to seven distinct axial rings. Three pairs of pleural ribs distinct, small, highly convex. Posterior border wide, almost flat. Four pairs of interpleural furrows, incomplete; postaxial ridge or furrow developed.

Grinnellaspis newfoundlandensis sp. nov.
Plate 33, figures 1-6

1979a *Grinnelaspis* sp. nov. Boyce, page 8.
1979b *Grinnelaspis* sp. nov. Boyce.
1983a *Grinnellaspis* sp. nov. Boyce, pages 12, 13.

Diagnosis. Pygidium elliptical. Axial lobe composed of up to three axial rings of posteriorly decreasing distinctiveness. Postaxial furrow, wide, shallow, poorly defined. Prosopon of terrace-lines.

Etymology. For my adopted province of Newfoundland, where this species was discovered.

Stratigraphic range. Barbace Cove Member of the Boat Harbour Formation, 71.80 to 93.60 m above the base of the Boat Harbour composite section.

Material. Eight (8) cranidia; nine (9) librigenae; twelve (12) pygidia.

Holotype. Pygidium, NFM F-170, from BH-60 in the Barbace Cove Member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated).

Paratypes. Cranidium, NFM F-166 from BH-60; librigena, NFM F-167 from BH-60; pygidium, NFM F-168 from BH-40; pygidium, NFM F-169 from BH-49; pygidium, NFM F-171 from BH-69; all in the Barbace Cove Member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated).

Description. Glabella transversely broadly vaulted, straight- and parallel-sided, anteriorly evenly rounded; it extends about five-sevenths total cranidial length. Occipital ring incompletely preserved but well defined; it extends one-seventh total cranidial length. Preglabellar, axial and occipital furrows distinct, narrow, deep. Lateral glabellar furrows not developed. Preglabellar field wide, about one-seventh total cranidial length, anteriorly downsloping. Anterior border furrow indistinct. Anterior border wide, about one-seventh total cranidial length—of constant width, strongly concave, in anterior view straight. Anterior fixigenal areas wide, anteriorly downsloping. Anterior portions of facial suture display strongly convex-outward profile. Palpebral fixigenal areas wider than anterior fixigenal areas by about 1.5x, abaxially horizontal to gently upsloping, exsagittally anteriorly gently downsloping. Palpebral lobes large, semicircular, long—exsagittal length about two-fifths total sagittal glabellar length. Palpebral furrow not developed. Line through centres of palpebral lobes crosses glabellar sagittal line at about one-half glabellar length from posterior edge of occipital ring. Posterior fixigenal areas not preserved. Prosopon consists of terrace-lines on occipital ring. Prosopon not preserved on remainder of cranidium.

Hypostoma not known.

Librigenae long, broadly triangular, strongly convex. Lateral border strongly concave, abaxially tapering. Prosopon smooth except for genal spine, where it consists of terrace-lines perpendicular to the lateral margin.

Thorax not known.

Pygidium elliptical, length about seven-tenths to three-quarters maximum width. Axial lobe transversely broadly arched, straight-sided, posteriorly tapering and abruptly rounded; it extends about one-half total pygidial length. As many as three axial rings of posteriorly decreasing distinctiveness. Axial furrows distinct, narrow, deep. Pleural fields small, triangular, strongly convex in comparison to posterior border. Three pairs of pleural ribs. Three pairs of pleural furrows distinct, narrow, deep, extend only to posterior border furrow. Posterior border furrow indistinct, wide, shallow. Posterior border wide, at least one-half total pygidial length, flat to weakly convex and posteriorly gently downsloping. Four pairs of interpleural furrows distinct, wide,

shallow, incomplete–extend only from posterior border furrow to posterior margin. Postaxial furrow less distinct, wider; it extends from axis to posterior margin. Prosopon consists of terrace-lines parallel to posterior margin.

Remarks. The small number of axial rings and the development of a postaxial furrow rather than a ridge readily distinguishes *G. newfoundlandensis* from *G. feildeni*.

Grinnellaspis newfoundlandensis and *Punka* sp. nov. (Boyce, 1985, = *Punka?* sp. indet., Fortey, 1979a; Plate 33, figures 1-10; Plate 35, figures 12, 14, 15) share the following morphological features:

1) anterior borders wide, concave,
2) glabellas straight- and parallel-sided, anteriorly evenly rounded,
3) palpebral lobes large, semicircular,
4) librigenae long, broadly triangular; lateral border concave, abaxially tapering,
5) pygidia subelliptical to elliptical,
6) pygidial axial lobes short, straight-sided,
7) pygidial pleural fields small, convex,
8) posterior borders wide, flat,
9) pleural and interpleural furrows incomplete, and
10) prosopons of terrace-lines.

On the basis of the above morphological similarities and the fact that *Punka* species stratigraphically succeed *Grinnellaspis* species in western Newfoundland, it is suggested that *Punka* evolved directly from *Grinnellaspis*. The following morphological changes are observed:

1) glabella increases in length,
2) librigenae become longer and narrower,
3) maximum number of axial rings in the pygidium decreases from seven to five,
4) pygidial pleural fields become less convex and the pleural ribs less distinct from the posterior border, and
5) the postaxial ridge/furrow disappears.

The pygidia of *Punka* sp. nov. (see Fortey, 1979a, page 91; Plate 35, figures 12, 14, 15) illustrates the last three changes above, while it retains the shape of *G. newfoundlandensis*. This species occurs stratigraphically between *G. newfoundlandensis* and *P. flabelliformis* at Eddies Cove West and Port au Choix.

Genus *Uromystrum* Whittington, 1953

Type species. Bathyurellus validus Billings, 1865, from the Table Point Formation (Table Point Group) at Pointe Riche, western Newfoundland (designated by Whittington, 1953).

Diagnosis. See Whittington *in* Moore (1959, page O380).

Uromystrum affine (Poulsen, 1937)
Plate 33, figures 7-10; Plate 34, figures 1-4

1937 *Bathyurellus affinis* n. sp. Poulsen, page 55; Plate 7, figures 6, 7.
1978 *Uromystrum* sp. Boyce, page 83.
1979a *Uromystrum* sp. nov. Boyce, page 8.
1979b *Uromystrum* sp. nov. Boyce.
1983 *Uromystrum affine* (Poulsen); Boyce *in* Stouge and Boyce; Plate 14, figures 4, 5; Plate 15, figure 3.
1983b *Uromystrum affine* (Poulsen); Boyce, pages 173-175; Plate 17, figures 1-4.

Diagnosis. Glabella weakly defined. Occipital ring not developed. Pygidial axial lobe effaced. Posterior border wide, concave-upward.

Stratigraphic range. Lower limestone sequence of the Catoche Formation, 89.18 to 93.60 m above the base of the Boat Harbour composite section; lower limestone sequence of the Catoche Formation, 1.34 to 4.79 m above the base of the Cape Norman section.

Material. Eight (8) cranidia; eleven (11) librigenae; twenty-eight (28) pygidia.

Holotype. Pygidium, MMH 3705, from the Cape Weber Formation on Ella Island in east-central Greenland (the original of Poulsen, 1937; Plate 7, figure 7–by monotypy).

Description. Cranidium highly effaced, strongly convex. Glabella weakly convex, transversely broadly arched slightly above level of palpebral fixigenae, straight- and parallel-sided. Axial furrows almost indistinct, narrow, shallow, disappear at point along line jointing divergence points of anterior branches of facial suture. Preglabellar and occipital furrows not developed. Lateral glabellar furrows not developed. Anterior fixigenal areas and preglabellar field wide, convex, anteriorly steeply downsloping. Anterior border transversely long, sagittally wide, broadly convex-forward, gently concave-upward, smooth, abaxially gently tapering; defined by distinct, abrupt, broadly convex-forward change in slope. Anterior branches of facial sutures strongly divergent. Palpebral fixigenal areas abaxially and exsagittally steeply downsloping. Palpebral lobes not preserved. Posterior fixigenal areas apparently very small, posteriorly steeply downsloping. Posterior border furrows not developed. Prosopon smooth.

Hypostoma unknown.

Librigena with genal field strongly convex, extending directly backward into long, equally convex genal spine. Lateral border poorly defined, wide, gently concave-upward, abaxially disappears rapidly. Posterior border not developed. Prosopon smooth.

Thorax unknown.

Pygidium weakly convex, almost flat, semicircular, length about one-half maximum width at posterior end of articulating facets. Anterior margin straight. Articulating half-ring sagittally narrow, almost nonexistent. Articulating facets sagittally narrow, parallel to anterior margin. Axial lobe almost indistinct, slightly concave-sided, posteriorly tapering and abruptly rounded. Axial furrows faint, almost nonexistent. Pleural field narrow, subtriangular, displays obscure furrows. Posterior border wide, concave-upward—of nearly constant width, postaxially slightly wider than at anterior margin. Prosopon smooth.

Remarks. The wide, concave-upward pygidial border of *U. affine* readily distinguishes it from *Uromystrum* sp. cf. *U. affine* (Poulsen), which it most closely resembles.

Uromystrum sp. cf. *U. affine* (Poulsen, 1937)
Plate 34, figure 5

1979a *Uromystrum* cf. *affine* (Poulsen); Fortey, pages 99, 100, 110 and 111; Plate 37, figures 10, 11.
1983a *Uromystrum* sp. nov. 2 Boyce, page 12.
1983b *Uromystrum forteyi* sp. nov. Boyce, pages 176-178; Plate 17, figure 5.

Diagnosis. Pygidial axial lobe distinct. Posterior border narrow, concave-upward.

Stratigraphic range. Lower limestone sequence of the Catoche Formation, 5.93 to 21.06 m above the base of the Cape Norman section.

Material. Twenty-six (26) librigenae; nine (9) pygidia.

Description. Cranidium, hypostoma, and thorax unknown.

Librigena with genal field weakly convex, extending directly backward into long, equally convex genal spine. Lateral border well defined, wide, concave-upward, abaxially tapering to end of genal spine. Posterior border not developed. Anterior and posterior sections of facial suture strongly divergent. Palpebral sections of facial suture small, indicates species has small palpebral lobes. Prosopon smooth.

Pygidium semicircular, length about one-half width. Axial lobe and pleural region effaced, but axial lobe quite distinct for *Uromystrum*. Posterior border narrow—of even width, concave-upward. Less effaced individuals display the following features (see Fortey, 1979a, Plate 37, figure 10):

1) articulating half-ring almost nonexistent, sagittally narrow,
2) articulating facets sagittally narrow, parallel to anterior pygidial margin,
3) axial lobe almost indistinct, slightly concave-sided, posteriorly tapering and abruptly rounded. Axial furrows faint; two anterior axial rings weakly defined, and
4) one pair of furrows, faint, incomplete, in the median portion of the anterior pleural field.

The posterior border is better defined and appears to exhibit a greater degree of concavity in the smaller, less effaced individuals.

Remarks. Fortey (1979a, pages 99, 100) has already pointed out the differences between *Uromystrum* sp. cf. *U. affine* and *U. affine*, which the former most closely resembles. At the time, because the cranidia and librigenae of neither species were known, he believed there was insufficient evidence to diagnose a new species from Newfoundland. Since then, more specimens of both species' pygidia have been collected from both within Fortey's original study area, as well as from outside it (Boyce, 1983a,b, 1985, 1986).

In the Boat Harbour—Cape Norman region, *Uromystrum* sp. cf. *U. affine* appears stratigraphically later than *U. affine* and because of the similarity of the two species, pygidia, is regarded as its direct evolutionary descendent.

Although no cranidium attributable to *Uromystrum* sp. cf. *U. affine* was found at Cape Norman, a likely candidate exists. *'Bathyurellus' marginiatus* Billings, 1865 is known from a single cranidium obtained from the Catoche Formation on Keppel Island (Fortey, 1979a; Plate 35, figures 11, 13). The outline of the facial sutures, and the width and concavity of the anterior border of this species, closely matches the outline of the facial sutures and the adaxial width of the lateral border on the librigenae of *Uromystrum* sp. cf. *U. affine*. *Uromystrum* sp. cf. *U. affine* (Poulsen) will probably prove to be a junior synonym of *Uromystrum marginiatus* (Billings). However, the problem will remain unsolved until the appropriate cranidia and pygidia are found together.

Superfamily PROETACEA Salter, 1864
Family DIMEROPYGIDAE Hupé, 1953
Genus *Ischyrotoma* Raymond, 1925

Type species. Ischyrotoma twenhofeli Raymond, 1925, from the Cow Head Group at Lower Head, western Newfoundland.

Ischyrotoma parallela sp. nov.
Plate 34, figures 7, 8; Plate 35, figures 1-10

1978 *Ischyrotoma* sp. (in part) Boyce, page 83.
1979a *Ischyrotoma anataphra* Fortey (in part); Boyce, page 8.
1979b *Ischyrotoma* sp. nov. Boyce.
1983a *Ischyrotoma* sp. nov. Boyce, page 12.
1983 *Ischyrotoma* sp. Boyce *in* Stouge and Boyce; Plate 13, figure 3.

Diagnosis. Glabella straight- and parallel-sided, strongly forward-protruding. Anterior border furrow distinct. Anterior border transversely long, narrow, convex. Prosopon of coarse tubercules.

Etymology. From the Latin *parallelus* parallel, referring to the sides of the glabella (feminine).

Stratigraphic range. Lower limestone sequence of the Catoche Formation, 90.66 to 93.60 m above the base of the Boat Harbour composite section; lower limestone sequence of the Catoche Formation, 1.34 to 1.64 m above the base of the Cape Norman section.

Material. Eighteen (18) cephalons; three (3) cranidia; eight (8) librigenae.

Holotype. Cephalon, NFM F-178 from BH-101/BH-110 in the lower limestone sequence of the Catoche Formation at Boat Harbour, western Newfoundland (here designated).

Paratypes. Cephalons, NFM F-86 from BH-100, NFM F-179 from BH-112; both in the lower limestone sequence of the Catoche Formation at Boat Harbour, western Newfoundland (here designated).

Description. Cephalon highly convex with broad anterior arch. Librigenae attached almost vertically to cranidium. Glabella highly convex, transversely strongly vaulted, straight- and parallel-sided, subrectangular, anteriorly gently rounded, forward-protruding; it overhangs anterior border. Forward glabellar outline semicircular. Occipital ring sagittally narrow, rectangular. Preglabellar, occipital and axial furrows well defined, deep; occipital furrow wider than preglabellar and axial furrows. Two pairs of indistinct, anteriorly directed lateral glabellar furrows occur on the sides of the glabella at about mid-length of cephalon. Preglabellar field narrow, vertical, convex. Anterior border furrow distinct. Anterior border transversely long, narrow, convex. Posterior fixigenal areas triangular, about four-fifths transverse width of occipital ring. Posterior border furrows well defined, deep. Posterior border narrow, convex. Anterior portions of facial suture converge slightly in front of eyes, strongly so in front of anterior border; posterior portions diverge at an angle of about 53°. Librigenae with lateral border furrows well developed. Genal spines if present not preserved. Eyes convex, placed at about cephalic mid-length. Prosopon of coarse tubercules except for anterior and lateral borders. Tuberculation reflected on internal moulds.

Hypostoma, thorax and pygidium unknown.

Remarks. Ischyrotoma parallela most closely resembles the stratigraphically early forms of *I. anataphra* Fortey (1979a; Plate 36, figures 2, 3, 10, 12). The strongly forward-protruding, straight- and parallel-sided glabella and the well defined anterior border of *I. parallela*, however, readily distinguish the two species. The stratigraphically early forms of *I. anataphra* are viewed as intermediate forms on a direct evolutionary line between *I. parallela* and the stratigraphically late forms of *I. anataphra*. *Ischyrotoma parallela* differs from the (younger) type species *I. twenhofeli* Raymond (Whittington, 1963; Plate 7, figures 1-13) in that the glabella is straight- and parallel-sided and the preglabellar field is slightly larger.

Ischyrotoma anataphra Fortey, 1979a
Plate 34, figure 6

1978 *Ischyrotoma* sp. (in part) Boyce, page 83.
1979a *Ischyrotoma anataphra* sp. nov. Fortey, pages 104, 106; Plate 36, figures 1-13.
1979a *Ischyrotoma anataphra* Fortey (in part); Boyce, page 8.
1979b *Ischyrotoma* sp. nov. (in part) Boyce.
1983b *Ischyrotoma anataphra* Fortey; Boyce, pages 182-183; Plate 18, figure 4.
1986 *Ischyrotoma anataphra* Fortey; Fortey, Plate 1, figures 4,5

Diagnosis. Glabella anteriorly slightly tapering and abruptly rounded. Preglabellar field sagittally short. Anterior border indistinctly defined. Prosopon of coarse tubercules on stratigraphically early forms; on stratigraphically later forms tuberculation less pronounced, especially on librigenae. Genal spines small. Diagnosis modified from Fortey (1979a, page 104).

Stratigraphic range. Lower limestone sequence of the Catoche Formation, 4.44 to 21.06 m above the base of the Cape Norman section.

Material. Thirty-seven (37) cephalons; fifteen (15) cranidia; seventeen (17) librigenae; two (2) pygidia.

Holotype. Cephalon, GSC 56879, from the Catoche Formation on Port au Choix Peninsula, western Newfoundland (Fortey, 1979a—by monotypy).

Paratypes. Cephalons, GSC 56880, GSC 56887; cranidium, GSC 56881; pygidia, GSC 57758, GSC 56882; all from the Catoche Formation on Port au Choix Peninsula (Fortey, 1979a—by monotypy).

Remarks. As Fortey (1979a) has already provided a detailed description of *I. anataphra*, it is not repeated here.

Superfamily CHEIRURACEA Öpik, 1937
Family PLIOMERIDAE Raymond, 1913
Subfamily CYBELOPSINAE Fortey, 1979a
Genus *Strotactinus* Bradley, 1925

Type species. Amphion salteri Billings, 1861 from the Oxford Formation of southeastern Ontario.

Diagnosis. See Harrington *in* Moore (1959, page O444).

Strotactinus insularis (Billings, 1865)
Not figured

1865 *Amphion insularis* (N. sp.) Billings, pages 280-291.
1979a *Strotactinus insularis* (Billings); Fortey, pages 108, 110-111; Plate 37, figures 1-9.

Diagnosis. Strotactinus species with anterior cranidial border strongly reflexed over frontal glabellar lobe. On pygidium, five completely defined axial rings; sixth axial segment clearly indicated on long (sagittally), inflated terminal piece. Distal tips of pygidial pleural spines turn outwards. Diagnosis from Fortey (1979a, page 108).

Stratigraphic range. Lower limestone sequence of the Catoche Formation, 11.67 to 21.06 m above the base of the Cape Norman section.

Material. Two (2) cranidia; six (6) pygidia.

Neotype. Pygidium, GSC 56884, from the Catoche Formation on Port au Choix Peninsula (selected by Fortey, 1979a, page 108–by monotypy).

Remarks. As Fortey (1979a) has already provided a detailed description of *S. insularis*, it is not repeated here.

Family INCERTAE SEDIS
Genus *Randaynia* nov.

Type species: Randaynia saundersi sp. nov. from the Boat Harbour Formation on Old Ferrolle Island, Brig Bay, western Newfoundland (here designated).

Diagnosis. Cranidium highly convex, featureless except for concave anterior border, thorax with six or seven segments. Pygidium featureless except for 1) weakly defined axial lobe, which is posteriorly tapering and abruptly rounded or truncated, and 2) distinct posterior border, which is flat to concave and of constant width. Prominent pair of tubercules generally developed at posterior end of axial lobe.

Etymology. In honor of the late objectivist philosopher Ayn Rand.

Assigned species: Species that are assigned to *Randaynia* nov. (in addition to those described in this study) include: 1) *Bathyurus taurifrons* Dwight from the Rochdale Formation (Wappinger Group) at Rochdale, Dutchess County, New York (Dwight, 1884, pages 252-253; Plate VII, figures 1-3), 2) *Bathyurus perkinsi* Whitfield from the Fort Cassin Formation (Beekmantown Group) at the mouth of Otter Creek, Vermont (Whitfield, 1897, page 183; Plate V, figures 7, 8), and 3) *Asaphellus gyracanthus* Raymond from the Tribes Hill Formation (Beekmantown Group) of the Mohawk Valley (Raymond, 1910, pages 39, 40; Plate XIV, figures 5-7 and Fisher, 1954, pages 85, 87, 89, 90; Plate 4, figure 10).

The unidentified pygidium illustrated by Ross (1951; Plate 26, figure 15) from Zone G in the Garden City Formation of northeastern Nevada is questionably assigned to *Randaynia;* it may actually belong to *Isoteloides* or some other asaphid genus.

Remarks: Randaynia most closely compares with *Bellefontia* Ulrich *in* Walcott, 1924 and *Parabellefontia* Hintze, 1953. The differences are discussed below.

Randaynia is generally more effaced than *Bellefontia;* the cranidial and pygidial axes are not as well developed. In addition, the cranidial anterior border, the librigenal lateral border and the pygidial posterior border are concave-upward rather than convex-upward as in *Bellefontia. Randaynia* also has no more than seven thoracic segments; see *R. saundersi (this study;* Plate 36, figure 4). *Bellefontia* has at least eight thoracic segments; see *B. ibexensis* Hintze (1953; Plate IV, figure 6).

Randaynia is more strongly furrowed than the monotypic *Parabellefontia.* The cranidial and pygidial axes are better defined; in *Parabellefontia* they are not developed. In addition, the cranidial anterior border and librigenal lateral border are strongly developed; they are lacking in *Parabellefontia.* Furthermore, the pygidium of *Randaynia* has a strongly developed posterior border, which is also much wider than that of *Parabellefontia.* See Boyce *(this study;* Plate 37, figures 1-10; Plate 38, figures 7-11) and Hintze (1953; Plate III, figures 1-8) to photographically compare the two genera.

Randaynia differs from both *Bellefontia* and *Parabellefontia* in that the posterior end of the pygidial axis displays a prominent pair of tubercules *(this study;* Plate 37, figures 1-10; Plate 38, figure 7-11). The latter two genera do not exhibit this feature.

Undetermined genus and species No. 2 of Ross (1958, pages 567, 568; Plate 84, figures 1, 2, 13-15) from the Valmy Formation of Nevada may be closely related to but not congeneric with *Randaynia.* Although the cranidium and librigenae are comparable with those of *Randaynia,* particularly *R. langdoni* sp. nov., the pygidium lacks the distinctive flat to concave posterior border.

The prominent pair of tubercules on the posterior end of the pygidial axial lobes of *R. saundersi, R. langdoni* and *R. taurifrons* suggests that *Randaynia* may belong to the subfamily Hystricurinae Hupé, 1953. Hystricurines such as *Hystricurus* and *Hillyardina* also display this feature. The outline of the glabella of *R. taurifrons* is also markedly hystricurid-like. However, the taxonomic assignment of *Randaynia* must await the discovery of a hypostoma.

Randaynia saundersi sp. nov.
Plate 36, figures 1-10; Plate 37, figures 1-10

1978 *Bellefontia?* cf. *B? acuminiferentis* Ross; Boyce, page 83.
1979a *'Parabellefontia'* sp. Boyce, page 8.
1979b *'Parabellefontia'* sp. nov. Boyce.
1983a *'Parabellefontia'* sp. Boyce, page 11.
1983 *'Parabellefontia'* sp. Boyce *in* Stouge and Boyce, 1983; Plate 14, figure 3; Plate 16; figure 9.

Diagnosis. Cranidium sagittally long; anterior border wide; glabella undefined; palpebral lobes small, crescentic. Librigenal lateral borders wide, abaxially tapering; posterior borders lacking; genal spines long, wide. Pygidium semicircular; posterior border wide, posteriorly gently downsloping. Prosopon consists of fine terrace-lines.

Etymology. For P.D. Saunders, who introduced the author to Ayn Rand's writings.

Stratigraphic range. Lower member of the Boat Harbour Formation, 9.84 to 66.14 m above the base of the Boat Harbour composite section.

Material. Sixty-four (64) cranidia; one hundred and twenty-eight (128) librigenae; two hundred and five (205) pygidia; one (1) nearly complete individual lacking librigenae; four (4) individuals lacking cephalons.

Holotype. Nearly complete, flattened individual lacking librigenae, NFM F-94, from the Boat Harbour Formation on Old Ferrolle Island, Brig Bay, western Newfoundland (here designated).

Paratypes. Cranidia, NFM F-119 from BH-18; NFM F-267 from BH-9; librigena, NFM F-117 from BH-30; pygidia, NFM F-120 from BH-23; NFM F-121 from BH-30; all from the Lower member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated).

Description. Cranidium sagittally long, strongly convex; glabella undefined except on smallest individuals (see Plate 36, figures 5-8). Preglabellar, occipital and lateral glabellar furrows not developed. Axial furrows weakly defined; they extend anteriorly to line joining posterior ends of palpebral lobes, rarely to line joining anterior ends of palpebral lobes. Anterior portion of cranidium highly convex, anteriorly steeply downsloping. Anterior border well defined, wide, abaxially tapering, and broadly arched in anterior view. Palpebral fixigenal areas of cranidium weakly convex, abaxially gently downsloping, exsagittally anteriorly gently to steeply downsloping. Palpebral lobes small, crescentic, short—exsagittal length about one-third total cranidial length; palpebral furrows not developed. Line through centres of palpebral lobes crosses cranidial sagittal line at about one-third cranidial length from posterior edge of cranidium. Posterior fixigenal areas of cranidium narrow, convex, triangular, posteriorly moderately steeply downsloping; posterior border furrow absent. Prosopon consists of very fine terrace lines parallel to anterior margin of cranidium, except for palpebral and fixigenal areas of cranidium, which are smooth. Internal mould smooth also.

Hypostoma unknown.

Librigena with genal field highly convex. Lateral border wide, concave, abaxially tapering. Genal spine long. Posterior border absent. Prosopon consists of fine terrace-lines, convex-forward on genal field and concave-forward on lateral border. On genal spine terrace-lines form forward-pointing tight chevron pattern.

Thorax consists of six or seven long, narrow segments of about equal size with large articulating half-rings. Pleural furrows distinct, narrow, deep, subparallel to anterior margins of pleurae. Axial furrows less distinct, narrow, shallow. Prosopon smooth except for fine, convex-forward terrace-lines on articulating half-rings.

Pygidium moderately convex, semicircular; length about three-fifths to two-thirds maximum width at posterior end of articulating facets. Axial lobe transversely weakly arched, posteriorly strongly tapering and abruptly truncated, weakly convex; it extends about three-quarters total pygidial length. Anterior axial ring may be weakly developed. Prominent pair of tubercules (possibly representing muscle insertion areas) at posterior end of axial lobe. Axial furrows weakly defined, narrow, shallow. Pleural and interpleural furrows generally not developed; however, weak pairs are displayed by pygidia greater than 1.5 cm in width. Posterior border well defined, wide—of constant width, flat to concave, posteriorly gently downsloping. Prosopon consists of fine terrace-lines parallel to posterior margin.

Randaynia langdoni sp. nov.
Plate 38, figures 1-11

1979a gen. et sp. nov. Boyce, page 8.
1979b gen. et sp. nov. 2 Boyce.

Diagnosis. Cranidium sagittally short; anterior border narrow; glabella, occipital ring and posterior border furrow weakly defined; palpebral lobes large, broadly crescentic. Librigenal lateral borders well defined, concave; genal spines short, narrow. Pygidium subelliptical; axis well defined; posterior border well defined, narrow, flat to concave, posteriorly steeply downsloping.

Etymology. For G.S. Langdon, fellow graduate student.

Stratigraphic range. Barbace Cove Member of the Boat Harbour Formation, 74.29 to 75.89 m above the base of the Boat Harbour composite section.

Material. Twenty-four (24) cranidia; seven (7) librigenae; eighty-two (82) pygidia.

Holotype. Pygidium, NFM F-125, from BH-47 in the Barbace Cove Member of the Boat Harbour Formation at Boat Harbour, western Newfoundland (here designated).

Paratypes. Cranidium, NFM F-123; librigena, NFM F-124; pygidium, NFM F-126; from the same horizon as the holotype (here designated).

Description. Cranidium sagittally short, strongly convex. Glabella weakly defined, wide, straight-sided, anteriorly slightly expanding and broadly rounded; it extends about nine-tenths total cranidial length. Occipital ring weakly defined, narrow, subrectangular. Preglabellar furrow weakly defined, narrow, shallow. Axial furrows equally faint, nearly indistinct. Occipital furrow well defined, slightly convex-forward, wide, shallow; best defined medially. Lateral glabellar furrows not developed. Faint median glabellar ridge developed anterior to line joining anterior ends of palpebral lobes. Preglabellar

field about one-twentieth total cranidial sagittal length. Anterior border well defined, narrow, concave, of constant width; flat in anterior view. Anterior fixigenal areas narrow, convex, anteriorly steeply downsloping. Palpebral fixigenal areas slightly wider, convex, abaxially and exsagittally steeply downsloping. Palpebral lobes large, long–exsagittal length about one-half glabellar sagittal length, broadly crescentic, weakly defined. Palpebral furrow nearly indistinct. Line through centres of palpebral lobes crosses glabellar sagittal line at about one-half glabellar length from posterior edge of occipital ring. Posterior fixigenal areas narrow, convex, triangular, posteriorly steeply downsloping. Posterior border furrow well defined, narrow, shallow. Posterior border flat to weakly convex, triangular (abaxially widening) posteriorly gently upsloping. Prosopon smooth.

Hypostoma unknown.

Librigena with genal field moderately convex. Lateral border well defined, narrow, concave; of constant width until a point immediately anterior to posterior edge of ocular facial suture, where it becomes abaxially tapering and disappears. Genal spine short, narrow. Prosopon smooth.

Thorax unknown.

Pygidium moderately convex, subelliptical; length about two-thirds to three-quarters maximum width at posterior end of articulating facets. Axial lobe well defined, transversely weakly arched, posteriorly strongly tapering and abruptly rounded to pointed, weakly convex; it extends about four-fifths total pygidial length. Axial rings generally not developed but eight prominent pairs of muscle insertion scars, as well as a median axial ridge occur on several specimens; up to four anterior axial rings have been observed in small specimens. Axial furrows well defined, narrow, shallow. One pair of distinct, narrow, deep, pleural furrows. An incomplete anterior pair of interpleural furrows cuts the posterior border only. On very small specimens, 2 to 3 pairs of pleural and interpleural furrows may be seen. Posterior border well defined, narrow, flat to concave, posteriorly steeply downsloping, of constant width. Prosopon smooth.

Remarks. The respective diagnoses of *R. langdoni* and *R. saundersi* serve to distinguish the two species. Examination of type material of *R.taurifrons* (Dwight, 1884) in the New York State Museum shows its cranidium is easily distinguished from those of *R. saundersi* and *R. langdoni* as the glabella is well defined, straight-sided and anteriorly tapering and abruptly rounded. Long posterior fixigenal areas are also developed.

ACKNOWLEDGMENTS

The completion of this study would have been impossible without the continuing and unwavering enthusiasm, encouragement and moral support of several individuals throughout the years. Chief among these have been Drs. I. Knight and R.V. Gibbons (Newfoundland Department of Mines and Energy), Dr. R.K. Stevens (Memorial University of Newfoundland, Department of Earth Sciences) and Dr. F.J. Aldrich (Chairman, Ocean Studies Task Force, Memorial University of Newfoundland). I specially thank Dr. R.A. Fortey (British Museum–Natural History) for unofficial supervision of the M.Sc. thesis, on which this study is based, and stimulating discussions during 1977-1978, while he was on sabbatical leave at Memorial University of Newfoundland. The following people in no small measure also contributed by their friendship to the completion of this study: G.W. Hillier, G.S. Langdon, D.N. Reusch, P.D. and C.M. Saunders, J.L. Smith and S.S. Stouge.

Dr. B. Greene (Assistant Deputy Minister, Newfoundland Department of Mines and Energy) suggested the topic of this study. Dr. A.R. Palmer (formerly of the State University of New York at Stony Brook) is thanked for his understanding, when I decided to stay at Memorial University of Newfoundland, despite having been accepted for graduate studies at Stony Brook.

I gratefully acknowledge the financial support of the Natural Sciences and Engineering Research Council in the form of two Postgraduate Scholarships. The Newfoundland Department of Mines and Energy generously provided field support during the course of this study. The Department of Graduate Studies (Memorial University of Newfoundland) provided a four month Graduate Fellowship.

The fossil collecting expertise of Chris Pinsent (1984) and Stephen Ash (1984-1987) was greatly appreciated. Austin Patey (River of Ponds), Lawrence Patey and family (Hawkes Bay) and Lyle Campbell and family (Cape Norman) are also thanked for their much appreciated assistance and hospitality.

Dr. C.H. Kindle (Nyack, New York) provided access to his outstanding collection of western Newfoundland trilobites, which was greatly appreciated. The following people are also gratefully acknowledged for the loan of trilobite material under their care: N. Eldredge and J. Golden (American Museum of Natural History), T.E. Bolton and M.J. Copeland (Geological Survey of Canada), S. Floris and V. Poulsen (Geologisk Museum), F.J. Collier (United States National Museum, Smithsonian Institution) and J.S. Lawless, K. Waage and R.D. White (Yale Peabody Museum of Natural History). The bulk of the loans were arranged by Drs. R.A. Fortey and D. Skevington (formerly of Memorial University of Newfoundland). T.E. Bolton and M.J. Copeland (Geological Survey of Canada), J.W. Cowie (Bristol University), N. Eldredge and J. Golden (American Museum of Natural History), R.A. Fortey and S.F. Morris (British Museum–Natural History), E. Landing (New York State Museum), D.M. Rudkin and J. Waddington (Royal Ontario Museum) and A.W.A. Rushton (Institute of Geological Sciences) are thanked for their permission to examine relevant trilobite collections at their respective institutions.

Drs. D. Skevington and L.E. Fahraeus served in their respective terms as official thesis supervisors. Drs. R.K.

Stevens and C.R. Barnes subsequently joined Dr. Fahraeus as adjunct supervisors.

The technical support of a number of individuals has been of great importance and cannot be overemphasized. Bev Strickland has been particularly meticulous and efficient with the word processing and typesetting. Additional textwork has been cheerfully and capably performed by Mary Byrne and Debbie Downey. Dr. I. Knight carefully proofread the various manuscripts and suggested a number of improvements. Drs. R. Ludvigsen (Denman Institute for Research on Trilobites, British Columbia) and C.R. Barnes (Geological Survey of Canada) read specific portions of the original thesis manuscript and also made helpful suggestions for improvements. Ken Byrne, Desirée King, Dave Leonard and Tony Paltanavage are thanked for their patient and expert drafting services. Winston Augustus Poindexter III is heartily acknowledged for his photographic expertise; additional photographic assistance was provided by Wilf Marsh (Memorial University of Newfoundland, Earth Sciences) and Gary McManus (Memorial University of Newfoundland, Geography). The staff of the Emergency Department at the Health Sciences Complex are thanked for getting my eye back in operation so quickly.

I am indebted to Drs. R. Ludvigsen and R.K. Stevens for critically examining and reviewing the original thesis manuscript. Dr. R.A. Fortey also merits special thanks for reviewing the subsequent draft.

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APPENDIX 1

MEASURED STRATIGRAPHIC SECTIONS–BOAT HARBOUR

Six sections were measured along the shore, northeast of Boat Harbour. The base of the measured sequence is a 1.48-m-thick bed, containing distinctive chert-rimmed algal mounds, which occurs 45 m above the base of the Lower member of the Boat Harbour Formation (Knight, 1980b; Stouge, 1981). This bed is located in the village of Boat Harbour on the southern shore of the cove, south of Boat Head. The top of the measured sequence is situated about 3.5 km northeast of the village at the top of a 15 m+ cliff, landward of a wave-cut platform. The cumulative thickness of the measured sequence is 93.60 m.

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES
SECTION BHS-6: DESCENDING SECTION TO THE SOUTHWEST TOWARD BOAT HARBOUR			
	Top of Section BHS-6 and Measured Boat Harbour Sequence		93.60
	ST. GEORGE GROUP		
	CATOCHE FORMATION lower limestone sequence		
41	LIME MUDSTONE and WACKESTONE: dark grey, light blue-grey and rubbly weathering, massive, moderately bioturbated; burrows, buff weathering, dolomitized; birdseye calcite and white, sparry calcite-lined fenestrae In the 662 cm of this unit, 19 fossil collections were made (BH-95A to BH-114), including 4 from various levels on the scree slope developed along the sides of the cliff formed by this unit, on the underlying bed (BH-101, BH-109, BH-110 and BH-112). Because the fossils had to be obtained from a vertical cliff face, collections were not complete. Articulate brachiopods, cephalopods, gastropods, ostracodes, and trilobites were collected. *Petigurus nero* collected 60 to 662 cm above base of unit (BH-95A to BH-114); *Strigigenalis caudata* collected 191 and 375 cm above base (BH-96 and BH-102); *Uromystrum affine* collected 220 to 662 cm above base (BH-97 to BH-114); *Jeffersonia angustimarginata* collected 222 to 662 cm above base (BH-98 to BH-114); *Grinnellaspis newfoundlandensis*, *Ischyrotoma parallela* and *Catochia ornata* collected 368 to 662 cm above base of bed (BH-100 to BH-114); *Bolbocephalus convexus* collected 385 to 662 cm above base (BH-104 to BH-114); *Benthamaspis hintzei* collected 562 to 662 cm above base (BH-108 to BH-114); *Isoteloides peri* collected 585 to 662 cm above base (BH-112).	6.62+	93.60
	BOAT HARBOUR FORMATION Barbace Cove Member		
40	LIME MUDSTONE and WACKESTONE: dark blue-grey, light blue-grey weathering: DOLOMITE MUDSTONE and WACKESTONE and/or DOLOMITE laminae, very thin and planar interbedded, extremely well laminated near top of bed. Laminations disrupted but not displaced by probable mudcracks; vertical contorted laminations indicative of shrinkage also seen. Top surface of bed mudcracked This unit forms the top of the Barbace Member of the Boat Harbour Formation. The contact between the Boat Harbour and Catoche formations occurs at the top of the bed.	2.42	86.98
39	LIME MUDSTONE, WACKESTONE, PACKSTONE and GRAINSTONE: locally intraclastic, dark blue-grey, light blue-grey weathering, thin and irregularly bedded; thin, buff DOLOMITE laminae; some horizontal bioturbation; intraclasts flat pebbles up to 7 cm in diameter, and 2-cm thick. Top of unit marked by thin, 10-cm thick marker bed of LIME MUDSTONE and WACKESTONE, dark blue-grey, light blue-grey and recessive weathering	4.24	84.56

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES
	The unit is abundantly fossiliferous, altogether the most fossiliferous in the Boat Harbour measured sequence. In the 424 cm of the unit, 41 fossiliferous horizons were sampled (BH-55 to BH-95). *Isoteloides peri* collected 5 to 424 cm above base (BH-55 to BH-95); *Strigigenalis brevicaudata* collected 16 to 424 cm above base (BH-56 to BH-95); *Bolbocephalus convexus* collected 34 to 356 cm above base (BH-59 to BH-94); *Grinnellaspis newfoundlandensis* collected 34 to 97 cm above base (BH-59 to BH-81); *Jeffersonia angustimarginata* and *Bolbocephalus stevensi* collected 34 to 424 cm above base (BH-59 to BH-95); *Petigurus nero* collected 34 to 100 cm above base (BH-69 to BH-83); *Benthamaspis hintzei* collected 50 cm above base (BH-62); a 27-cm thick blue and yellow weathering marker bed contains *Isoteloides peri* and articulate brachiopods, 268 cm above base; *Strigigenalis caudata* (Billings), collected 356 cm above base (BH-94); articulate brachiopods collected 414 to 424 cm above base (BH-95).		
38	LIME PACKSTONE and GRAINSTONE: intraclastic, dark blue-grey; intraclasts subangular to subrounded, up to 3.5 cm in length and 2 cm in diameter, LIME MUDSTONE and WACKESTONE, pink to reddish Bed contains brachiopods, trilobites. *Grinnellaspis newfoundlandensis* and *Strigigenalis brevicaudata* collected from bed; *Petigurus nero* collected 6 cm above base (BH-54)	0.10	80.32
37	LIME MUDSTONE, WACKESTONE, PACKSTONE and GRAINSTONE: thin bedded, irregular, buff to yellow weathering dolomitic laminae up to 5-mm thick, commonly enclosing lenses of matrix Trilobite cross-sections seen.	0.68	80.22
36	DOLOMITE MUDSTONE and WACKESTONE: dark grey, thin and irregularly bedded. Bed pinches out to the northeast	0.05(av.) 0.04-0.06	79.54
35	DOLOMITE BOUNDSTONE: stromatolitic, buff–mottled. Mounds exceptionally well preserved (diameters of 8, 15 and 33 cm observed), truncated by overlying bed, pinches out to the northeast. Mound interfill consists of LIME and DOLOMITE PACKSTONE and GRAINSTONE, intraclastic, buff weathering, blue-mottled; intraclasts up to 10-cm long	0.10	79.49
34	LIME PACKSTONE and GRAINSTONE: blue-grey, thin bedded; thin, irregular, buff dolomitic laminae Bed contains brachiopods, cephalopods, echinoderm debris, gastropods, and trilobites. *Jeffersonia angustimarginata*, *Bolbocephalus convexus* and *Peltabellia knighti* collected from bed; *Grinnellaspis newfoundlandensis* collected 25 cm above base (BH-53).	0.52	79.39
33	LIME MUDSTONE and WACKESTONE: blue-grey, massive; thin, irregular, buff dolomitic laminae; local patches of LIME PACKSTONE and GRAINSTONE Bed contains brachiopods, cephalopods, gastropods, and trilobites. *Jeffersonia angustimarginata*, *Bolbocephalus convexus* and *Peltabellia knighti* collected from bed; *Strigigenalis brevicaudata* collected 20 cm above base (BH-52).	0.65	78.87
32	DOLOMITE MUDSTONE and WACKESTONE: dark grey, buff to grey weathering, thin bedded, finely laminated. Bed is 35-cm thick in extreme southwest, 40-cm thick in extreme northeast. EXCELLENT MARKER BED	0.38(av.) 0.35-0.40	78.22
31	LIME MUDSTONE and WACKESTONE: blue-grey, extensively bioturbated relative to underlying bed	0.31	77.84

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES
30	LIME MUDSTONE and WACKESTONE: blue-grey, thin bedded; thin, irregular buff dolomitic laminae; bioturbation more common toward top of bed. Top of bed BOUNDSTONE, stromatolitic, thrombolitic; circular mounds up to 25 cm in diameter and up to 8 cm in elevation above top of bed Coiled cephalopods, gastropods seen in bed. *Strigigenalis brevicaudata* collected from top of bed; *Jeffersonia angustimarginata*, *Bolbocephalus convexus* and *Bolbocephalus stevensi* collected from mounds (BH-51).	0.35	77.53
29	LIME MUDSTONE and WACKESTONE: blue-grey slightly irregular surface displaying buff, dolomitized trails Beds contains cephalopods, high-spired and planispiral gastropods, and trilobites. *Bolbocephalus convexus* recovered 8 cm above base of bed (BH-50).	0.13	77.18
28	LIME MUDSTONE and WACKESTONE: blue-grey, massive, internally thin bedded; thin, buff weathering dolomitic laminae; scattered lenses of LIME PACKSTONE and GRAINSTONE throughout. Bioturbation most common toward top of bed; burrows buff weathering, dolomitized. Bottom of bed irregular. Bed ranges from 85 to 95 cm in thickness from southwest to northeast, respectively; bed thickens and thins before gradually reaching maximum thickness; where thickest, 10 to 13 cm of darker blue-grey LIME PACKSTONE and GRAINSTONE forms base of bed Bed contains articulate brachiopods and trilobites. *Jeffersonia angustimarginata* collected 25 to 90 cm above base of bed; *Peltabellia* sp. cf. *P. peltabella* collected 35 to 90 cm above base; *Bolbocephalus convexus* collected 63 to 90 cm above base; *Petigurus nero* and *Grinnellaspis newfoundlandensis* collected 70 to 90 cm above base (BH-49).	0.90(av.) 0.85-0.95	77.05
27	DOLOMITE PACKSTONE–GRAINSTONE and MUDSTONE–WACKESTONE: light blue-grey, buff weathering, mudcracked on top surface. Bottom and top surfaces of bed irregular. Bed ranges between 13 and 17 cm in thickness due to undulose top of underlying mound bed	0.15(av.) 0.13-0.17	76.15
26	LIME MUDSTONE and WACKESTONE: light blue-grey; BOUNDSTONE, stromatolitic, dark blue-grey. Mounds rarely vuggy, range in diameter from 8 to 50 cm; maximum elevation above rest of bed is 11 cm Bed contains high-spired gastropods; straight cephalopods and planispiral gastropods collected from top of bed (BH-48).	0.11	76.00
25	LIME BOUNDSTONE: stromatolitic, dark blue-grey. Mounds large, isolated, steep-sided, circular to slightly elliptical, up to 150 cm in diameter; mound tops taken as top of bed, elevated 43 cm above rest of bed. Mound interfill consists of LIME MUDSTONE, WACKESTONE, PACKSTONE, and GRAINSTONE, slightly lighter in colour than mounds, thin bedded. Minor thin horizons of LIME PACKSTONE and GRAINSTONE near base of bed Bed abundantly fossiliferous, contains articulate brachiopods, curved and coiled cephalopods, high-spired and planispiral gastropods, and trilobites. *Bolbocephalus convexus*, *Bolbocephalus stevensi*, *Hystricurus crassilimbatus*, and *Randaynia langdoni* collected 0 to 155 cm above base of bed; *Peltabellia knighti* collected 0 to 127 cm above base; *Strigigenalis brevicaudata* collected 111 to 155 cm above base; *Peltabellia crassimarginata* collected 115 cm above base; *Benthamaspis hintzei* collected 125 cm above base (BH-47).	1.55	75.89
24	LIME PACKSTONE AND GRAINSTONE: dark blue-grey, massive. Abundantly fossiliferous 'hash' bed contains straight cephalopods, high-spired and planispiral gastropods, and trilobites. *Peltabellia knighti* collected 0 to 33 cm above base of bed; *Bolbocephalus convexus* and *Randaynia langdoni* collected 28 to 33 cm above base (BH-46)	0.33	74.34

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES
23	LIME MUDSTONE and WACKESTONE: light blue-grey, thin and irregularly bedded: buff dolomitic laminae *Bolbocephalus convexus* and high-spired and planispiral gastropods collected 21 to 36 cm above base of bed (BH-45).	0.36	74.01
22	LIME PACKSTONE and GRAINSTONE: light blue-grey *Peltabellia knighti*, planispiral gastropods collected 11 cm above base of bed (BH-44).	0.14	73.65
21	LIME MUDSTONE and WACKESTONE: light blue-grey, thin and irregularly bedded; buff dolomitic laminae; minor, thin (3 cm) LIME PACKSTONE and GRAINSTONE beds also occur *Bolbocephalus convexus*, orthid brachiopods, cephalopods, and high-spired and planispiral gastropods collected 19 cm above base of unit (BH-42); *Bolbocephalus convexus* also collected 57 cm above base (BH-43).	0.62	73.51
20	LIME PACKSTONE and GRAINSTONE: intraclastic, light blue-grey. 26-cm long intraclast seen. Bed appears to grade 2 cm down into underlying bed. Fossil fragments visible	0.05	72.89
19	LIME PACKSTONE and GRAINSTONE: light blue-grey	0.22	72.84
18	LIME MUDSTONE and WACKESTONE: thin and irregularly bedded; thin, irregular, wispy, buff to yellow weathering dolomitic laminae *Bolbocephalus convexus* collected 10 to 15 cm above base of bed (BH-41). Gastropods seen at top of bed.	0.24	72.62
17	LIME MUDSTONE and WACKESTONE: light blue-grey, planar bedded, containing small, circular algal(?) mounds that project up to 5 cm above top of bed	0.05	72.38
16	LIME PACKSTONE and GRAINSTONE: intraclastic, light blue-grey, massive, cross-laminated; intraclasts up to 1 cm in diameter	0.33	72.33
15	LIME MUDSTONE and WACKESTONE: light blue-grey, thin bedded; buff to yellow weathering dolomitic laminae	0.09	72.00
14	LIME PACKSTONE and GRAINSTONE: intraclastic, light blue-grey; subangular to subrounded clasts up to 1 cm in diameter	0.08	71.91
13	LIME MUDSTONE and WACKESTONE: light blue-grey, thin bedded; thin, irregular, buff to yellow weathering dolomitic laminae *Strigigenalis brevicaudata*, *Grinnellaspis newfoundlandensis*, and *Jeffersonia angustimarginata* collected 3 cm below top of bed (BH-40).	0.21	71.83
12	DOLOSTONE:(diagenetic?), medium blue-grey, dark grey weathering, planar bedded, finely crystalline. Tiny planispiral gastropods seen	0.14	71.62
11	DOLOSTONE:(diagenetic?), light blue-grey, buff weathering, massive, finely crystalline; rare, tiny, rounded black CHERT clasts up to 5 mm in size	0.29	71.48
	BOAT HARBOUR FORMATION Lower member		
10	DOLOMITE WACKESTONE: argillaceous, dark grey, draped over undulose surface of 'pebble bed'	0.01	71.19

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES
9	DOLOSTONE: diagenetic, light blue-grey, buff weathering, finely crystalline, containing i) subangular to well rounded, white vug–QUARTZ clasts up to 3 cm in diameter, ii) angular grey to black CHERT clasts up to 6 cm long, iii) subangular to subrounded grey CHERT clasts containing tiny PYRITE crystals, and iv) PYRITE nodule clasts up to 1 cm in diameter. Small, straight, symmetrical, bimodal ripples measuring 052° seen. Bed has irregular, undulose top This is the 'pebble bed' of Knight (1978, p. 143) and Boyce (1978, p. 81, 83; 1979a, p. 8, 9).	0.06(av.) 0.05-0.06	71.18
8	DOLOSTONE: diagenetic, light blue-grey, buff weathering, massive, planar bedded, bioturbated(?), finely crystalline	0.43	71.12
7	DOLOSTONE: diagenetic, light blue-grey, buff weathering, massive, planar bedded, bioturbated, finely crystalline	0.37	70.69
6	DOLOSTONE: diagenetic, light blue-grey, buff weathering, rippled, bioturbated, finely crystalline. Straight symmetrical ripples–060° bimodal direction. Bed thins slightly to northeast (to 7 cm)	0.09	70.32
5	LIME MUDSTONE and WACKESTONE: medium blue-grey, massive, essentially planar bedded, extensively bioturbated; burrows light grey, dolomitized. Numerous elongate, elliptical, circular and irregular patches of ultra-extensive bioturbation evident on top surface of bed, locally aligned. Largest patch 569 by 325 cm, another 112 by 50 cm. Orientation of patches' long axes as follows: 304°, 318°, 318°, 322° and 340°. Patches start 14 cm above base of bed, in general are 45-cm thick. Most are almost pure diagenetic DOLOSTONE, the burrows having been dolomitized, although the smaller ones appear to be less so. The patches have slightly upturned rims. They became smaller and disappear to the northeast, and the bed surface appears less extensively bioturbated	0.59	70.23
4	LIME MUDSTONE and WACKESTONE: dark grey, thin and planar bedded, extensively bioturbated (horizontally). Top 27 cm more massive, also has vertical bioturbation Planispiral gastropods collected 4 to 42 cm above base of bed (BH-39), also seen on top of bed.	0.77	69.64
3	LIME MUDSTONE and WACKESTONE: dark grey, massive, planar bedded, sparsely bioturbated	0.20	68.87
2	LIME MUDSTONE and WACKESTONE: dark grey, massive, planar bedded, extensively bioturbated (vertically)	0.24	68.67
1	LIME MUDSTONE and WACKESTONE: dark grey, massive, planar bedded, extensively bioturbated (horizontally). Bed contains planispiral gastropods	0.40	68.43
	Base of Section BHS-6		68.03

Note: The top 2.20 m of Section BHS-5 are equivalent to Beds 1 to 5 of Section BHS-6. The top of Bed 5 of BHS-6 is, therefore, 70.23 m above the base of the measured Boat Harbour sequence and the base of Bed 1 of BHS-6 is 68.03 m above the base.

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES
	SECTION BHS-5: DESCENDING SECTION TO SOUTHWEST		
	Top of Section BHS-5		70.23
1	LIME MUDSTONE and WACKESTONE: light blue-grey, rubbly weathering, massive, extensively bioturbated; burrows, trails buff, dolomitized Gen. nov. A sp. nov. A and *Diaphelasma* collected 248 to 278 cm above base of unit; *Randaynia saundersi*, *Parahystricurus smithiae* and *Hillyardina levis* collected 268 to 278 cm above base only (BH-37). *Hillyardina levis* and Gen. nov. A sp. nov. A collected 285 cm above base (BH-38).	6.87	70.23
	Base of Section BHS-5		63.36
	Note: Knight (1977b, Fig. 6) gives a thickness of 7.97 m for the covered interval below, however, Pratt (1979, Appendix F, Unit 120) gives a thickness of 2.0 m. This second figure is believed to be more accurate and is therefore utilized.		
	COVERED INTERVAL	2.00	63.36
	SECTION BHS-4: DESCENDING SECTION TO SOUTHWEST		
	Top of Section BHS-4		61.36
4	LIME BOUNDSTONE: thrombolitic, dark blue-grey, rubbly weathering, massive. Mound complexes large, 200 to 300 cm in diameter, built of smaller circular mounds, up to 40 cm in diameter, in a honeycomb arrangement—each 'cell' highlighted by silicified or buff, dolomitized, bioturbated rims, etc. Mound complex interfill consists of LIME MUDSTONE, WACKESTONE, PACKSTONE and GRAINSTONE, thin and essentially planar bedded *Hillyardina levis* collected 38 cm above base of unit (BH-35). Planispiral gastropods seen 64 to 230 cm above base; *Parahystricurus smithiae*, *Hillyardina levis*, cephalopods, and planispiral gastropods collected 100 cm above the base (BH-36).	2.30	61.36
3	LIME BOUNDSTONE: stromatolitic, light blue-grey and extremely rubbly weathering, well laminated; abundant black CHERT. Mounds include LLH, SH-V and club-shaped forms (similar to those of Shark Bay, Australia). Some LLH stromatolites only 28 cm in maximum thickness, others 56 ± 3 cm thick. SH-V stromatolites extend to top of bed. Some circular mounds, 40 cm in diameter. Mound interfill consists of LIME PACKSTONE and GRAINSTONE, oölitic, silicified; it caps the thinner stromatolites	0.80	59.06
2	LIME MUDSTONE AND WACKESTONE: light blue-grey; thin, irregular, buff dolomitic laminae; some intraclastic (flat-pebble) PACKSTONE and GRAINSTONE. Undulose top, probably stromatolitic	0.12	58.26
	Top of Bed 1 of Section BHS-4		58.14
	SECTION BHS-4: (CONTINUED BELOW BHS-4A UNIT 1a)		
	Note: A small fault oriented 065/74, interrupts the basal beds of Section BHS-4. The beds of Section BHS-4A have been downthrown 1.85 m to the southeast relative to those of Section BHS-4. The details of the restored BHS-4A Section are as follows:		

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES
	SECTION BHS-4A: DESCENDING SECTION TO SOUTHWEST		
	Top of Section BHS-4A		59.61
4a	LIME MUDSTONE and WACKESTONE: dark grey, rubbly weathering, massive *Randaynia saundersi*, *Hystricurus deflectus*, *Parahystricurus smithiae* and *Hillyardina levis*, cyrtoconic cephalopods and planispiral gastropods collected 0 to 25 cm above base of unit; Gen. nov. B. sp. nov. A collected 25 cm above base only (BH-34).	0.55	59.61
3a	LIME BOUNDSTONE: stromatolitic, as in Bed 3 of Section BHS-4. Mounds circular, well laminated. Diameter of stromatolite mounds as follows: 1) 40 to 55 cm at 40 cm above base of unit (LLH) 2) 30 cm at 50 cm above base 3) 22 cm at 62 cm above base 4) 10 cm at 70 cm above base Mound interfill consists of oölitic LIME PACKSTONE and GRAINSTONE, locally silicified, except from 58 to 80 cm above base of unit	0.80	59.06
2a	LIME MUDSTONE, WACKESTONE and BOUNDSTONE: dark blue-grey, light blue-grey weathering; thin, irregular, buff dolomitic laminae. Undulose upper surface due to pustular stromatolites, circular, up to 40 cm in diameter, flanked by intraclastic (flat-pebble) LIME PACKSTONE and GRAINSTONE	0.20	58.26
1a	LIME MUDSTONE and WACKESTONE: dark blue-grey, light blue-grey weathering, massive, overall planar bedded, internally thin and irregularly bedded; thin, buff dolomitic laminae	0.57	58.06
	Base of Bed 1A (Base of Section BHS-4A)		57.49
	SECTION BHS-4: (continued)		
	Note: Bed 1 of Section BHS-4 directly overlies Bed 18 of Section BHS-3, and is in part stratigraphically equivalent to Bed 19 of Section BHS-3, as stated below.		
1	LIME MUDSTONE and WACKESTONE: dark blue-grey, light blue-grey weathering, massive, overall planar bedded, internally thin and irregularly bedded; thin, irregular, buff dolomitic laminae; extensively bioturbated; burrows, trails buff, dolomitized. Layer of black CHERT defines base of bed. CHERT mostly yellow, but locally white-weathering; it occurs as irregular nodules and occasional lenses parallel to bedding *Hystricurus deflectus* and planispiral gastropods collected 90 to 80 cm below top of unit (BH-32). *Hystricurus deflectus* and Gen. nov. A sp. nov. A collected 63 to 119 cm above base of unit; *Randaynia saundersi*, *Parahystricurus smithiae* and *Hillyardina levis* collected 119 cm above base (BH-32A). *Randaynia saundersi*, *Hystricurus deflectus* and *Hillyardina levis* collected 40 to 25 cm below top (BH-33). *Randaynia saundersi* collected 129 cm above base of unit (BH-33A).	1.50	58.14
	Top of Bed 18 of Section BHS-3 (Base of Section BHS-4)		56.64

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES
SECTION BHS-3: DESCENDING SECTION TO SOUTHWEST			
	Top of Section BHS-3		57.86
19	LIME MUDSTONE and WACKESTONE: light blue-grey, rubbly weathering, massive; buff dolomitic laminae; extensively bioturbated. Basal 15 cm of bed BOUNDSTONE, stromatolitic, light blue-grey, less massive, not bioturbated; mounds LLH, approximately 20 to 30 cm in diameter. This bed is stratigraphically equivalent to the lower 1.22 m of Bed 1 of Section BHS-4 *Hystricurus deflectus*, *Parahystricurus smithiae* and Gen. nov. A sp. nov. A collected 25 to 80 cm above base of bed; *Randaynia saundersi* collected at 80 cm above base only (BH-31).	1.22	57.86
18	DOLOMITE MUDSTONE and WACKESTONE: light grey, thin, irregularly bedded. DOLOMITE BOUNDSTONE, stromatolitic, 100 to 120 cm above base of bed—mounds LLH, approximately 30 cm in diameter	1.33	56.64
17	LIME MUDSTONE, WACKESTONE, PACKSTONE and GRAINSTONE: intraclastic, dark blue-grey, massive, hard, sparsely bioturbated. Intraclasts subrounded, up to 1.5 cm in diameter, LIME MUDSTONE and WACKESTONE. Bed has hummocky surface *Randaynia saundersi*, *Hillyardina levis*, *Parahystricurus smithiae*, and planispiral gastropods collected 10 cm below top of bed (BH-30).	0.90	55.31
16	LIME MUDSTONE and WACKESTONE: light blue-grey, thin, planar bedded; thin, irregular, buff dolomitic laminae	0.75	54.41
15	LIME BOUNDSTONE: stromatolitic and thrombolitic, blue-grey, rubbly weathering, massive—essentially the same lithologies present as in Bed 6 of BHS-2 except for CHERT rimming the mounds. *Randaynia saundersi*, *Hystricurus deflectus*, *Parahystricurus smithiae*, *Hillyardina levis* collected, planispiral gastropods seen 100 to 25 cm below top of bed (BH-29).	1.73	53.66
14	DOLOMITE MUDSTONE and WACKESTONE: buff to light grey weathering, massive, bioturbated	0.64	51.93
13	LIME MUDSTONE and WACKESTONE: thin and irregularly bedded; thin, irregular, buff dolomitic laminae; moderately bioturbated. Base and top of bed undulose *Hystricurus oculilunatus*, *Parahystricurus smithiae*, *Hillyardina levis*, *Diaphelasma*, echinoderm fragments, and high-spired and planispiral gastropods collected 87 to 65 cm below top of bed (BH-28).	1.30	51.29
12	LIME BOUNDSTONE: stromatolitic and thrombolitic, dark blue-grey, rubbly weathering, massive. Mounds large, built up by digitate stromatolites and thrombolites; beef-calcite structures seen. Mounds fossiliferous, although fossils small, hard to find. Mound interfill consists of blue-grey LIME MUDSTONE, WACKESTONE, PACKSTONE and GRAINSTONE and buff dolomitic material, thinly interbedded, locally extensively bioturbated. Top of bed extensively bioturbated *Randaynia saundersi*, *Hillyardina levis*, and orthid brachiopods collected; cross-section of large straight cephalopod seen 75 to 50 cm below top of bed (BH-26). Cephalopods and planispiral gastropods (some pyrite-filled) collected from top of bed (BH-27).	1.53(av.) 1.81-1.25	49.99

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES
11	DOLOMITE MUDSTONE and WACKESTONE: buff weathering, thin and irregularly bedded, extensively bioturbated. Top undulose, mound-like	0.52(av.) 0.24-0.80	48.46
10	LIME PACKSTONE and GRAINSTONE: blue-grey, thin, irregular and lenticular bedded; thin, interbedded buff dolomitic layers and laminae; extensively bioturbated; burrows, trails buff weathering	0.62	47.94
9	LIME MUDSTONE and WACKESTONE: Base of bed essentially planar; top undulose, possibly stromatolitic Planispiral gastropods collected from bed (BH-25).	0.22(av.) 0.20-0.25	47.32
8	LIME MUDSTONE and WACKESTONE: rubbly weathering, massive, sparsely bioturbated *Randaynia saundersi*, *Hystricurus deflectus*, *Parahystricurus smithiae*, *Hillyardina levis*, cephalopods, and planispiral gastropods collected 18 to 63 cm above base of bed; *Paraplethopeltis seelyi* collected from top of bed only, but also seen 25 cm below the top (BH-24).	0.63	47.10
7	LIME MUDSTONE AND WACKESTONE: blue-grey, thin and irregularly bedded; thin, irregular, buff dolomitic laminae; extensively bioturbated; burrows, trails on bedding plane surfaces, buff dolomitized. Planar top	0.22	46.47
6	LIME BOUNDSTONE: Stromatolitic. Mounds circular, up to 50 cm in diameter, 42 cm maximum thickness, pustular looking in plan view, built up by colloform columnar (SH-C) stromatolites, internally well laminated. Larger mound complexes up to 100 cm in diameter composed of 15 to 30 cm diameter coalesced mounds. Distance between mound complexes up to 150 cm. Mounds/mound complexes developed in depressions of underlying bed. Mounds/mound complex interfill consists of blue-grey lime MUDSTONE and WACKESTONE and buff dolomitic material, thin and flaser-bedded	0.42	46.25
5	LIME MUDSTONE and WACKESTONE: blue-grey, thin bedded; thin, buff dolomitic laminae, abundant bioturbation-burrows, trails buff, dolomitized. Bottom of bed slightly undulating. Top of bed depressed by overlying bed Fossils collected as in underlying bed except for Gen. nov. A sp. nov. A; *Hystricurus oculilunatus* also collected (BH-23).	0.24(av.) 0.22-0.27	45.83
4	LIME MUDSTONE and WACKESTONE: blue-grey, massive, internally thin and irregularly bedded; thin, irregular, buff dolomitic laminae; abundant bioturbation; burrows, trails, buff weathering, dolomitized. Top of bed gently undulating. *Randaynia saundersi*, *Hystricurus deflectus*, *Parahystricurus smithiae*, *Hillyardina levis*, Gen. nov. A sp. nov. A, *Diaphelasma*, orthid brachiopods, cephalopods, and planispiral gastropods collected 65 to 118 cm above base of bed (BH-22).	1.18	45.59
3	LIME MUDSTONE and WACKESTONE: blue-grey, thin and planar bedded; thin, planar, buff dolomitic laminae become less regular toward top of bed, some thin dolomitic interbeds at base	0.46	44.41
2	DOLOMITE MUDSTONE and WACKESTONE: light grey, massive, planar bedded, very thinly laminated	0.28	43.95
1	LIME MUDSTONE and WACKESTONE: dark grey, massive, internally thin and irregularly bedded; thin, irregular, buff dolomitic laminae Planispiral gastropods collected from top of bed (BH-21).	1.00+	43.67
	Base of Section BHS-3		42.67

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES

Note: Sections BHS-2 and BHS-3 are apparently in normal fault contact, with the beds of BHS-3 (on the northwestern side of the fault) downthrown relative to the beds of BHS-2. Both sides of the fault were examined, in detail, in order to find matching beds. Bed 9 of BHS-2 and Bed 12 of BHS-3 were found to be essentially of the same lithology and were, therefore, assumed to be the same bed. In addition, the top of Bed 9 of BHS-2 was assumed to be equivalent, stratigraphically, to the top of Bed 12 of BHS-3.

The predominantly covered interval between the tops of Beds 7 and 9 of BHS-2 was also measured and compared with the cumulative thickness of Beds 1 to 12 of BHS-3. This was done to check if Beds 1 to 12 of BHS-3 could be accommodated between Beds 7 and 9 of BHS-2, as might be expected; this was found to be the case. The covered interval between the tops of Beds 7 and 9 of BHS-2 was calculated to be 9.10 m, and the cumulative thickness of Beds 1 to 12 of BHS-3 was measured to be 7.32 m. This leaves a covered interval of only 1.78 m between sections BHS-2 and BHS-3.

For the above Section BHS-3, the top of Bed 12 is assumed to be 49.99 m above the base of the measured Boat Harbour sequence (i.e. stratigraphically equivalent to the top of Bed 9 of BHS-2, as stated above).

SECTION BHS-2: DESCENDING SECTION TO SOUTHWEST

	Top of Section BHS-2		49.99
9	See description for Bed 12 of Section BHS-3	0.50(av.) 0.30-0.70	49.99
	COVERED INTERVAL	7.70	49.49
8	LIME MUDSTONE and WACKESTONE: dark blue-grey, light blue-grey weathering, planar base and top, internally thin and irregularly bedded; thin, irregular, buff weathering dolomitic laminae	0.30	41.79
	COVERED INTERVAL	0.60	41.49
7	LIME MUDSTONE and WACKESTONE: dark blue-grey, light blue-grey weathering, thin and irregularly bedded; thin, irregular, buff weathering dolomitic laminae; sparsely bioturbated; horizontal trails buff weathering, dolomitic. Planar top High-spired and planispiral gastropods collected, one straight cephalopod seen 20 cm below top of bed (BH-20).	0.95	40.89
6	LIME BOUNDSTONE: stromatolitic, dark blue-grey, rubbly weathering, massive. Huge mounds, up to 300 cm in diameter and averaging 120 cm in thickness. Two mound horizons. Lower mounds developed on topographic highs of underlying bed and highs formed of stacked up edgewise flat pebble–conglomerate (intraclastic PACKSTONE and GRAINSTONE); they are built up by colloform digitate stromatolites and outlined by occasional layers of black CHERT. On top of lower mounds, circular rings of black CHERT 60 cm in diameter suggest that the large mounds are formed of smaller coalesced mounds. Lower mound interfill consists of alternating blue-grey LIME MUDSTONE, and WACKESTONE, PACKSTONE and GRAINSTONE and buff dolomitic material, thin bedded, planar laminated; CHERT also occurs in narrowest gaps between mounds. Upper mounds developed in depressions between lower mounds; they are built up by digitate stromatolites and also contain orange CHERT. Upper mound complexes isolated, distance between any two varying from 15 to 200 cm. Upper mound interfill consists of LIME MUDSTONE, WACKESTONE, PACKSTONE and GRAINSTONE, well bioturbated in wide intermound areas, vuggy (vugs lined by sparry CALCITE), and particularly fossiliferous	2.09	39.94

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES
	Randaynia saundersi, Hystricurus deflectus, Parahystricurus smithiae, Hillyardina levis, Diaphelasma, cephalopods, and planispiral gastropods collected from mound interfill 109 to 159 cm above base of bed (BH-18). *Randaynia saundersi, Hystricurus deflectus, Hillyardina levis*, cephalopods, and planispiral gastropods collected 189 to 209 cm above base (BH-19).		
5	DOLOSTONE: Buff. Bioturbation evident near planar base. Top undulose, laminated, contains flasers of LIME MUDSTONE and WACKESTONE, blue-grey Planispiral gastropods collected from top of bed (BH-17).	0.22(av.) 0.16-0.27	37.85
4	LIME MUDSTONE and WACKESTONE: blue-grey, thin bedded, sparsely bioturbated, although local patches of abundant organic traces occur on bedding plane surfaces; burrows, trails buff, dolomitic High-spired gastropods seen and planispiral gastropods and partly silicified cephalopod collected 54 cm above base of bed (BH-15). *Hystricurus oculilunatus, Diaphelasma*, echinoderm fragments and planispiral gastropods collected 82 to 115 cm above base (BH-16). High-spired gastropods seen 80 to 85 cm above base.	1.96	37.63
3	LIME MUDSTONE and WACKESTONE: blue-grey, massive; buff, dolomitic burrows. Top of bed slightly irregular due to presence of LIME BOUNDSTONE mounds, 50 to 80 cm in diameter, elevated 15 cm above rest of bed. Top of mounds taken as top of bed Planispiral gastropods collected 30 to 67 cm above base of bed; cephalopod *(?Bassleroceras)* seen in a vertical orientation 39 cm above base also collected (BH-14).	0.67	35.67
2	LIME MUDSTONE and WACKESTONE: blue-grey, thin and planar bedded; thin beds or laminae of buff, dolomitic material	0.61	35.00
1	LIME MUDSTONE and WACKESTONE: dark grey (when wet), massive, extensively bioturbated—ramifying network of buff, dolomitic burrows cuts matrix	2.20+	34.39
	Base of Section BHS-2		32.19

Note: Between Sections BHS-1 and BHS-2, there are two covered intervals with some intervening unfossiliferous pseudobreccia beds generally exposed only at low tide. The author has accepted Knight's (1977b, Fig. 6) thickness values for these intervals.

	COVERED INTERVAL	4.23	32.19
	DOLOMITE BOUNDSTONE: buff weathering, diagenetic pseudobreccia mounds	2.88	27.96
	COVERED INTERVAL	5.00	25.08
SECTION BHS-1: DESCENDING SECTION TO SOUTHWEST			
	Top of Section BHS-1		20.08
23	DOLOMITIC LIME MUDSTONE and WACKESTONE to PACKSTONE and GRAINSTONE: dark grey, light blue-grey weathering, thin and irregularly bedded, sparsely bioturbated, vuggy—vugs buff, QUARTZ- or CHERT-lined *Hystricurus oculilunatus, Hillyardina minuspustulata*, echinoderm fragments and planispiral gastropods collected 24 cm above base of unit (BH-13).	1.19	20.08

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES
22	LIME MUDSTONE and WACKESTONE: blue-grey, massive, internally thin bedded, bioturbated horizontally and vertically; burrows, trails buff, dolomitized. Beds of LIME PACKSTONE and GRAINSTONE seen, well cross-laminated, bioturbated, very fine grained Planispiral gastropods seen in bioturbated beds. *Hystricurus oculilunatus*, *Hillyardina minuspustulata* and planispiral gastropods collected 32 to 42 cm above base of bed (BH-12).	1.13	18.89
21	LIME MUDSTONE and WACKESTONE to PACKSTONE and GRAINSTONE: blue-grey, thin and irregularly bedded; buff weathering dolomitic laminae; sparsely bioturbated (mostly horizontal bioturbation); symmetrical and interference ripple marks in upper part of bed. Bimodal ripple marks—266°, 308°, 325°, 326°, 328°, 352°, 004°	0.77	17.76
20	DOLOMITIC LIME MUDSTONE and WACKESTONE TO PACKSTONE and GRAINSTONE: blue-grey, more planar, thin bedded; buff dolomitized laminae, abundant dolomitized trails on bedding surfaces. Basal 10 cm consists of DOLOMITE PACKSTONE and GRAINSTONE, buff to blue, cross-laminated	0.40	16.99
19	LIME MUDSTONE and WACKESTONE: (dolomitic?), blue-grey weathering, massive, internally thin and irregularly bedded; thin, irregular, buff weathering dolomitic laminae; sparsely bioturbated; burrows, trails buff, dolomitized	0.77	16.59
18	DOLOMITIC LIME/LIMY DOLOMITE MUDSTONE and WACKESTONE: dark grey, medium grey weathering, massive, internally thin and irregularly bedded; irregular, buff dolomitic laminae; sparsely bioturbated; burrows, trails buff to dark brown, dolomitized	1.30	15.82
17	LIME MUDSTONE and WACKESTONE: blue-grey, massive, extensively bioturbated; burrows buff, dolomitized	0.43	14.52
16	LIME MUDSTONE and WACKESTONE: (dolomitic?), massive, internally thinly laminated, bioturbated; laminae, burrows buff, dolomitized	1.77	14.09
15	LIME MUDSTONE and WACKESTONE: dark blue-grey, light blue-grey weathering, massive; buff dolomitic laminae	0.27	12.32
14	LIME MUDSTONE and PACKSTONE: (dolomitic?) dark blue-grey, light blue-grey weathering, thin bedded, well laminated; planar and irregular, buff dolomitic laminae. Thin layers of intraclastic (flat-pebble) PACKSTONE and GRAINSTONE also occur in bed; clasts are flat, subangular to subrounded, up to 3 cm in diameter, and lie flat, scattered over bedding plane surfaces Planispiral gastropods collected approximately 130 cm above base of bed (BH-11).	1.48	12.05
13	LIME BOUNDSTONE: Constitute the upper 118 cm of bed, consists of stromatolitic and thrombolitic, darker blue-grey, rubbly weathering, massive, internally thinly and wispily laminated. Mound interfill consists of LIME MUDSTONE, WACKESTONE, PACKSTONE and GRAINSTONE, blue-grey, thin bedded, with more buff dolomitic laminae than present in mounds. A thin 1-cm layer of buff dolostone was seen between two mounds. An intraclastic PACKSTONE–GRAINSTONE dyke(?) was seen penetrating 40 cm into the unit. Topographic imperfections even out progressively toward top of bed LIME MUDSTONE and WACKESTONE and buff DOLOMITE PACKSTONE and GRAINSTONE: Constitute the middle 55 cm of the bed, well laminated	2.07	10.57

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES
	and interbedded. Bottom 30 cm is massive, well laminated, buff DOLOMITE PACKSTONE and GRAINSTONE: top 25 cm is mostly thin bedded, light blue-gray LIME MUDSTONE and WACKESTONE with abundant thin, buff DOLOMITE PACKSTONE and GRAINSTONE laminae. Bed of constant thickness, drapes over and follows contours of underlying mounds. Consequently, one part of the bed may be elevated 18 cm above another part close by		
	LIME and DOLOMITE BOUNDSTONE: Constitute the basal 34 cm of the bed, thrombolitic. Mounds are isolated, circular, up to 200 cm in diameter and up to 34-cm thick. Centres of mounds are generally elevated 18 cm above edges. Mounds cored by dark blue-grey DOLOMITIC LIMESTONE and rimmed by buff weathering; vuggy pseudobrecciated diagenetic DOLOSTONE; vugs contain rhombic DOLOMITE, pseudobreccia veins contain crypto-crystalline DOLOMITE and purple FLUORITE. Mounds are replaced by massive, buff, diagenetic DOLOSTONE to the northeast *Hillyardina minuspustulata, Randaynia saundersi,* the clarkellid brachipod *Diaphelasma* and planispiral gastropods collected 134 to 187 cm above base of bed (BH-9), *Hillyardina minuspustulata, Randaynia saundersi,* echinoderm fragments and planispiral gastropods collected from top of bed, cyrtoconic cephalopod *(?Bassleroceras)* also seen (BH-10).		
12	DOLOMITIC LIME MUDSTONE and WACKESTONE: dark grey, thin bedded, less extensively bioturbated; burrows, trails dolomitized Planispiral gastropods collected near middle of bed (BH-8).	0.58	8.50
11	DOLOMITIC LIME MUDSTONE and WACKESTONE: dark buff weathering, massive, internally thin bedded, extensively bioturbated; burrows, trails dolomitized Planispiral gastropods collected near top of bed (BH-7).	1.19	7.92
10	LIME BOUNDSTONE: stromatolitic and thrombolitic, grey weathering, massive. Basal 20 cm contains SH-C and SH-V lamination but rest of bed is structureless. Mounds are circular to irregular in shape, up to 100 cm in diameter and, except for weather pitting, have featureless top surfaces. Mound interfill consists of planar interbeds of coarse grained blue-grey LIME PACKSTONE and GRAINSTONE, buff DOLOMITE PACKSTONE and GRAINSTONE and dark grey dolomitic LIME MUDSTONE and WACKESTONE. The darker colour and buff dolomitic matrix of the mound interfill help outline the mounds Planispiral gastropods collected 36 cm above base of bed (BH-5). Curved (cyrtoconic) cephalopod as well as planispiral gastropods seen at top of bed (BH-6).	1.31	6.73
9	DOLOMITIC LIME MUDSTONE and WACKESTONE: dark grey, massive, extensively bioturbated; burrows dolomitized, more resistant to weathering Planispiral gastropods collected from bed (BH-4).	0.98	5.42
8	LIME BOUNDSTONE: stromatolitic and thrombolitic, blue-grey, rubbly weathering, massive. Mounds contain abundant buff weathering, irregular, wispy dolomitic laminae and quartz-lined vugs. Internal laminations in mounds suggest they are stromatolitic. Basal laminations are of LLH type; these change upward into SH-C and SH-V. Mound surfaces are irregularly pitted; the surface of the mound interfill is flat and smooth. Mound interfill consists of blue-grey LIME MUDSTONE and WACKESTONE and buff DOLOMITE PACKSTONE and GRAINSTONE, which is thin and flaser-bedded rather than massive and rubbly weathering. Interfill extends to top of bed and caps smaller mounds. Interfill laminations turned up at mound edges. Orientation of interfill channels 314° and 318°	0.75	4.44

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES
	Planispiral gastropods collected from mound interfill 6 to 10 cm above base of bed (BH-3).		
7	DOLOMITE PACKSTONE and GRAINSTONE: buff weathering, highly laminated and cross-laminated; occasional flasers of blue-grey LIME MUDSTONE and WACKESTONE.	0.15(av.) 0.10-0.20	3.69
6	LIME MUDSTONE and WACKESTONE: light blue-grey, thinner, less irregularly, more planar bedded; thin, buff weathering dolomitic laminae.	0.43	3.54
5	DOLOMITIC LIME MUDSTONE and WACKESTONE: light blue-grey, thin and irregularly bedded, sparsely bioturbated. Fossil trails buff, dolomitized. Erosive base cuts down as much as 10 cm into underlying bed. *Hystricurus oculilunatus* and planispiral gastropods collected 26 cm above base of bed (BH-1). Planispiral gastropods also collected 81 to 106 cm above base (BH-2)	1.06	3.11
4	DOLOMITIC LIME MUDSTONE and WACKESTONE: Light blue-grey weathering, planar bedded, flaser and cross-laminated; extremely thin, buff, dolomitic laminae. A scour or channel of intraclastic blue-grey PACKSTONE and GRAINSTONE occurs at the top of the bed and erodes down 1.2 cm into the densely laminated portion. The intraclasts are subangular to subrounded and up to 2 cm in diameter. The scour or channel is about 100-cm wide. Adjacent to it is another scour or channel 4- to 5-cm thick, and greater than 300 cm in lateral extent	0.37	2.05
3	DOLOSTONE: dark grey, white or very light grey weathering; thin, irregular, wispy algal lamination	0.08	1.68
2	CHERTY DOLOSTONE or DOLOMITIC CHERT: dark grey weathering, draped over underlying mounds; preserves thin, irregular, wispy laminations. Vugs of prismatic quartz	0.12(av.) 0.10-0.14	1.60
1	LIME MUDSTONE and WACKESTONE (dolomitic?), light grey (when fresh). Top 18 cm of bed consists of stromatolite mounds that are circular, distinctly laminated, composed of dolomite and rimmed by CHERT. Mounds are separate entities in early stages, later are linked. Silicified (CHERT) mound seen formed in the depression between the dolomitic mounds, although most commonly CHERT forms ridges separating dolomitic mounds	1.48	1.48

APPENDIX 2

MEASURED STRATIGRAPHIC SECTION–CAPE NORMAN

A detailed section was measured through the lower limestone sequence and the Diagenetic Carbonates of the Catoche Formation, exposed on the shore, below the lighthouse at Cape Norman. The base of the section was taken 21.06 m below the stratigraphic contact of the lower limestone sequence and the Diagenetic Carbonates. Unlike the beds of the Boat Harbour sequence, which dip to the northeast, the beds exposed at Cape Norman dip toward the southwest.

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES
	SECTION CNS-1: DESCENDING SECTION TO NORTHEAST		
	Top of Section CNS-1		27.06
	ST. GEORGE GROUP		
	CATOCHE FORMATION Diagenetic Carbonates		
4	DOLOSTONE: diagenetic, dark grey, light grey to yellow weathering, massive, medium- to coarse-crystalline, chert-bearing	6.00+	27.06
	lower limestone sequence		
3	LIME MUDSTONE and WACKESTONE: dark blue-grey weathering, thin rubbly bedded, bioturbated; top of bed contains thin lenses of skeletal LIME PACKSTONE and GRAINSTONE and spectacular patches of diagenetic DOLOSTONE–PSEUDOBRECCIA, white weathering	10.80	21.06
	Unit 3 more fossiliferous than Unit 1, especially near top in the thin lenses of skeletal LIME PACKSTONE and GRAINSTONE *Jeffersonia angustimarginata* collected 7.13 to 10.32 m above base of unit (CN-29 to CN-37); *Bolbocephalus convexus* collected 1.41 to 8.29 m above base (CN-20 to CN-32); *Petigurus nero* collected 0.00 up to 10.80 m from base (CN-17, in part to CN-38); *Strigigenalis caudata* collected 1.87 to 9.50 m above base (CN-21 to CN-35); *Catochia ornata* collected 0.72 to 9.50 m above base (CN-19 to CN-35); *Bolbocephalus kindlei* collected 1.87 m above base (CN-21); *Illaenus* sp. nov. collected 5.93 to 7.13 m above base (CN-29); *Bathyurellus abruptus* collected 1.41 to 10.80 m above base (CN-20 to CN-38); *Jeffersonia timon* collected 0.00 to 10.80 m above base (CN-17, in part to CN-38); *Ischyrotoma anataphra* collected 3.94 to 10.80 m above base (CN-25 to CN-38); *Uromystrum* sp. cf. *U. affine* collected 1.41 to 10.80 m above base (CN-20 to CN-38); *Benthamaspis conica* Fortey collected 1.41 to 8.01 m above base (CN-20 to CN-31); *Benthamaspis* sp. cf. *B. conica* collected 5.93 to 9.50 m above base (CN-29 to CN-35); *Strotactinus insularis* collected 1.41 to 10.80 m above base (CN-20 to CN-38); *Isoteloides latimarginatus* collected 5.55 to 5.71 m above base (CN-28). Whittington and Kindle (1969, p. 659) also report *Carolinites* sp. from this unit, probably the upper part where the lenses of skeletal lime packstone and grainstone are most common. Fortey (1979a, p. 64) also identified *Isoteloides peri*, *Punka flabelliformis*, *Bolbocephalus convexus*, *Benthamaspis* cf. *B. gibberula* and *Strotactinus insularis* from collections obtained by Whittington and Kindle (1969), at Cape Norman.		
2	DOLOSTONE: diagenetic grey weathering massive. *Petigurus nero* (Billings) and *Jeffersonia timon* (Billings) collected from limestone remnant 0.80 to 0.85 m above base of unit (CN-17, in part)	0.85	10.26
1	LIME MUDSTONE and WACKESTONE: dark blue-grey, light blue-grey weathering, thin and rubbly bedded, bioturbated; spectacular pipes and patches	9.41	9.41

UNIT	DESCRIPTION	UNIT THICKNESS IN METRES	CUMULATIVE THICKNESS IN METRES

of diagenetic DOLOSTONE–PSEUDOBRECCIA, white to light-grey weathering–one pipe seen to flare out horizontally and replace top 20 cm of a LIMESTONE bed 8.55 to 8.75 m above base of unit. Immediately east of measured section, stratigraphically equivalent beds totally dolomitized. This indicates that the stratigraphically succeeding Diagenetic Carbonates are transgressive to, as well as conformably overlying, the lower limestone sequence.

Jeffersonia angustimarginata collected 0.29 to 8.17 m above base of unit (CN-1 to CN-14); *Bolbocephalus convexus* collected 0.29 to 1.64 m above base (CN-1 to CN-2); *Petigurus nero* collected 1.34 to 7.42 m above base (CN-2 to CN-12); *Strigigeralis caudata* collected 7.72 to 7.77 m above base (CN-13); *Uromystrum affine* collected 1.34 to 4.79 m above base (CN-2 to CN-8); *Ischyrotoma parallela*, *Illaenus* sp. nov. and *Bolbocephalus kindlei* collected 1.34 to 1.64 m above base (CN-2); *Catochia ornata* collected 1.34 to 7.77 m above base (CN-2 to CN-13); *Bathyurellus abruptus* collected 1.34 to 8.17 m above base (CN-2 to CN-14); *Jeffersonia timon* collected 1.78 to 9.01 m above base (CN-3 to CN-16); *Ischyrotoma anataphra* collected 4.44 to 6.13 m above base (CN-7 to CN-10); *Uromystrum* sp. cf. *U. affine* collected 5.93 to 7.77 m above base (CN-10 to CN-13); *Benthamaspis conica* collected 7.22 to 7.77 m above base (CN-12 to CN-13); *Benthamaspis* sp. cf. *B. conica* collected 7.22 to 9.01 m above base (CN-12 to CN-16).

APPENDIX 3

LOCATION OF SAMPLED FOSSILIFEROUS HORIZONS–BOAT HARBOUR COMPOSITE SECTION

Horizon(s)	Distance Above Base of Section (Metres)	Distance Above Top of 'Pebble Bed' (Metres)
BH-114	93.00-93.10	21.82-21.92
113	92.85,93.60	21.67,22.42
112*	92.85	21.67-22.42
111	92.75	21.57
110*	92.70	21.52
109*	92.60	21.42
108	92.60	21.42
107	92.08	20.90
106	92.03	20.85
105	90.90	19.72
104	90.83	19.65
103	90.78	19.60
102	90.73	19.55
101*	90.66	19.48
100	90.66	19.48
99	89.24	18.06
98	89.20	18.02
97	89.18	18.00
96	88.89	17.71
95A	87.58-87.88	16.40-16.70
95	84.46-84.56	13.28-13.38
94	83.86-83.93	12.68-12.75
93	83.84	12.66
92	82.76	11.58
91	82.57	11.39
90	82.53	11.35
89	82.50	11.32
88	82.42-82.43	11.24-11.25
87	82.27	11.09
86	81.42	10.24
85	81.37	10.19
84	81.34	10.16
83	81.32	10.14
82	81.30	10.12
81	81.29	10.11
80	81.27	10.09
79	81.22	10.04
78	81.20	10.02
77	81.19	10.01
76	81.17	9.99
75	81.12	9.94
74	81.10	9.92
73	81.09	9.91
72	81.07	9.89
71	81.03-81.06	9.85- 9.88
70	81.01-81.02	9.83- 9.84
69	80.96-80.98	9.78- 9.80
68	80.95	9.77
67	80.92-80.94	9.74- 9.76
66	80.90	9.72
65	80.89	9.71
64	80.87	9.69
63	80.84	9.66

Horizon(s)	Distance Above Base of Section (Metres)	Distance Above Top of 'Pebble Bed' (Metres)
BH- 62	80.82	9.64
61	80.80	9.62
60	80.77-80.79	9.59- 9.61
59	80.66	9.48
58	80.62	9.44
57	80.56	9.38
56	80.48	9.30
55	80.37	9.19
54	80.28	9.10
53	79.12,78.87-79.39	7.94,7.69- 8.21
52	78.42,78.22-78.87	7.24,7.04- 7.69
51	77.53	6.35
50	77.13	5.95
49	76.40-77.05	5.22- 5.87
48	76.00	4.82
47	74.34-75.89	3.16- 4.71
46	74.01-74.34	2.83- 3.16
45	73.86-74.01	2.68- 2.83
44	73.62	2.44
43	73.46	2.28
42	73.08	1.90
41	72.48-72.53	1.30- 1.35
40	71.80	0.62

Horizon(s)	Distance Above Base of Section (Metres)	Distance Below Base of 'Pebble Bed' (Metres)
PEBBLE BED	71.12-71.18	----------
BH- 39	68.91-69.29	2.21- 1.83
38	66.21	4.91
37	65.84-66.14	5.28- 4.98
36	59.70-61.36	11.42- 9.76
35	59.44	11.68
34	59.06-59.31	12.06-11.81
33A	57.93	13.19
33	57.74-57.89	13.38-13.23
32A	57.27-57.83	13.85-13.29
32	57.24-57.34	13.88-13.78
31	56.89-57.44	14.23-13.68
30	55.21	15.91
29	52.66-53.41	18.46-17.71
28	50.42-50.64	20.70-20.48
27	49.99	21.13
26	49.24-49.49	21.88-21.63
25	47.10-47.32	24.02-23.80
24	46.65-47.10	24.47-24.02
23	45.59-45.83	25.53-25.29
22	45.06-45.59	20.06-25.53
21	43.67	27.45
20	40.69	30.43
19	39.74-39.94	31.38-31.18
18	38.94-39.44	32.18-31.68
17	37.85	33.27
16	36.49-36.82	34.63-34.30
15	36.21	34.91

Horizon(s)	Distance Above Base of Section (Metres)	Distance Below Base of 'Pebble Bed' (Metres)
14	35.30-35.67	35.82-35.45
13	19.13	51.99
12	18.08-18.18	53.04-52.94
11	11.87	59.25
10	10.57	60.55
9	9.84-10.37	61.28-60.75
8	8.21	62.91
7	7.92	63.20
6	6.73	64.39
5	5.78	65.34
4	4.44-5.42	66.68-65.70
3	3.75-3.79	67.37-67.33
2	2.86-3.11	68.26-68.01
1	2.31	68.81

Note: Collections by W.D. Boyce, summers 1976, 1977, 1978, 1985, 1987.

* indicates samples from float or talus.

APPENDIX 4

LOCATION OF SAMPLED FOSSILIFEROUS HORIZONS–CAPE NORMAN SECTION

Horizon(s)	Distance Above Base of Section (Metres)	Distance Below Base of Diagenetic Carbonates (Metres)
CN-38	20.86-21.06	0.20-0.00
37	20.43-20.58	0.63-0.48
36	20.27	0.79
35	19.46-19.76	1.60-1.30
34	19.11	1.95
33	18.55-18.90	2.51-2.16
32	18.27-18.55	2.79-2.51
31	18.01-18.27	3.05-2.79
30	17.83-17.97	3.23-3.09
29	16.19-17.39	4.87-3.67
28	15.81-15.97	5.25-5.09
27	15.14-15.39	5.92-5.67
26	14.96	6.10
25	14.20-14.67	6.86-6.39
24	13.78-13.91	7.28-7.15
23	12.78-12.85	8.28-8.21
22	12.24-12.34	8.82-8.72
21	12.13	8.93
20	11.67-11.74	9.39-9.32
19	10.98-11.01	10.08-10.05
18	10.39-10.63	10.67-10.43
17	10.21-10.33	10.85-10.73
16	8.94-9.01	12.12-12.05
15	8.55	12.51
14	7.87-8.17	13.19-12.89
13	7.72-7.77	13.34-13.29
12	7.22-7.42	13.84-13.64
11	6.91	14.15
10	5.93-6.13	15.13-14.93
9	5.16	15.90
8	4.74-4.79	16.32-16.27
7	4.44-4.49	16.62-16.57
6	3.89-4.09	17.17-16.97
5	3.64	17.42
4	2.43-2.53	18.63-18.53
3	1.78-1.83	19.28-19.23
2	1.34-1.64	19.72-19.42
1	0.29-0.34	20.77-20.72

Note: Collections by W.D. Boyce, September 1978, July–September, 1985.

APPENDIX 5

TRILOBITE SPECIES RANGES–BOAT HARBOUR COMPOSITE SECTION

Trilobite Species	Range of species above base of Boat Harbour composite section (Metres)
Catochia ornata (Fortey)	90.66-93.60
Ischyrotoma parallela sp. nov.	90.66-93.60
Uromystrum affine (Poulsen)	89.18-93.60
Strigigenalis caudata (Billings)	83.88-93.60
Isoteloides peri (Fortey)	80.37-93.60
Petigurus nero (Billings)	76.85-93.60
Peltabellia sp. cf. *P. peltabella* (Ross)	76.50-77.05
Benthamaspis hintzei sp. nov.	75.59-93.60
Peltabellia crassimarginata (Cullison)	75.49
Bolbocephalus stevensi sp. nov.	74.34-84.56
Hystricurus crassilimbatus (Poulsen)	74.34-75.89
Randaynia langdoni sp. nov.	74.29-75.89
Peltabellia knighti sp. nov.	73.62-79.39
Bolbocephalus convexus (Billings)	72.48-93.60
Jeffersonia angustimarginata sp. nov.	71.80-93.60
Grinnellaspis newfoundlandensis sp. nov.	71.80-93.60
Strigigenalis brevicaudata sp. nov.	71.80-84.56
Gen. nov. B. sp. nov. A	59.31
Paraplethopeltis seelyi (Whitfield)	46.85-47.10
Gen. nov. A. sp. nov. A	45.06-66.21
Hillyardina levis sp. nov.	38.94-66.21
Parahystricurus smithiae sp. nov.	38.94-66.14
Hystricurus deflectus (Heller)	38.94-59.31
Randaynia saundersi gen. et sp. nov.	9.84-66.14
Hillyardina minuspustulata sp. nov.	9.84-19.13
Hystricurus oculilunatus Ross	2.31-50.64

APPENDIX 6

TRILOBITES SPECIES RANGES–CAPE NORMAN SECTION

Trilobite Species	Range of species above base of Cape Norman section (Metres)
Isoteloides latimarginatus (Fortey)	15.81-15.97
Strotactinus insularis (Billings)	11.67-21.06
Benthamaspis sp. cf. *B. conica* (Fortey)	7.22-19.76
Benthamaspis conica (Fortey)	7.22-18.27
Uromystrum sp. cf. *U. affine* (Poulsen)	5.93-21.06
Ischyrotoma anataphra (Fortey)	4.44-21.06
Jeffersonia timon (Billings)	1.78-21.06
Bathyurellus abruptus (Billings)	1.34-21.06
Illaenus sp. nov.	1.34-17.39
Bolbocephalus kindlei sp. nov.	1.34-12.13
Catochia ornata (Fortey)	1.34-19.76
Ischyrotoma parallela sp. nov.	1.34- 1.64
Uromystrum affine (Poulsen)	1.34- 4.79
Strigigenalis caudata (Billings)	7.72-19.76
Petigurus nero (Billings)	1.34-21.06
Bolbocephalus convexus (Billings)	0.29-18.55
Jeffersonia angustimarginata sp. nov.	0.29-20.58

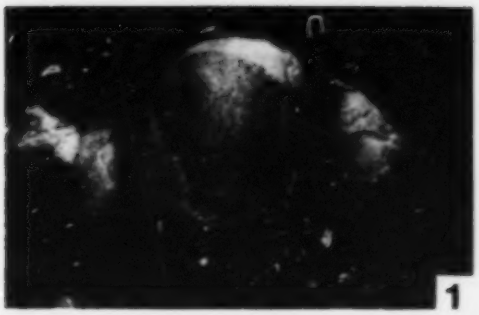
Plate 2

Leiostegium proprium sp. nov.

Lower member of the Boat Harbour Formation, Eddies Cove West, Unit 9 of Pratt's (1979) section.

Figures 1 to 5 **HOLOTYPE,** cranidium: dorsal, lateral, anterior, oblique anterior and inclined posterior views, NFM F-110, x 4.

Figures 6 to 9 **Paratype,** pygidium: dorsal, lateral, posterior and oblique posterior views, NFM F-111, x 6.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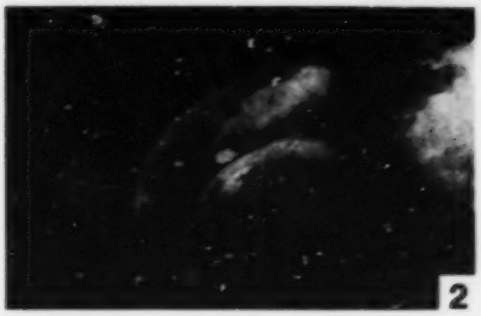
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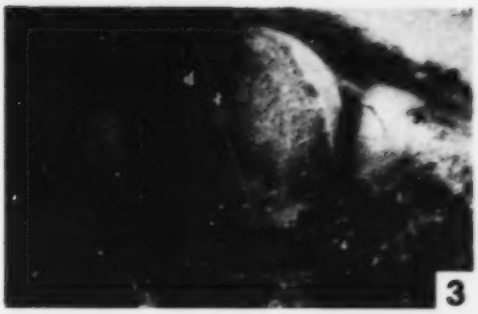
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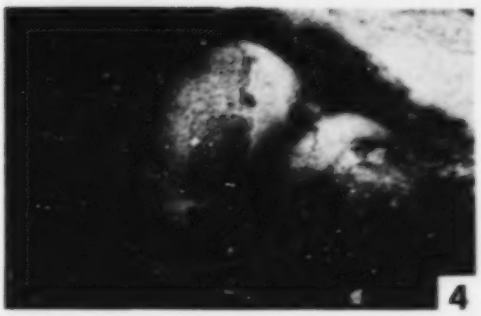
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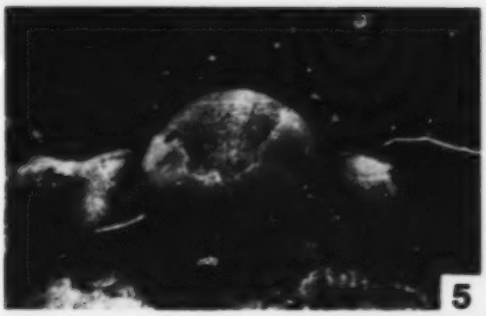
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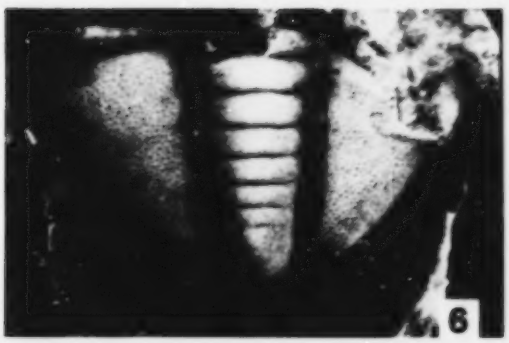
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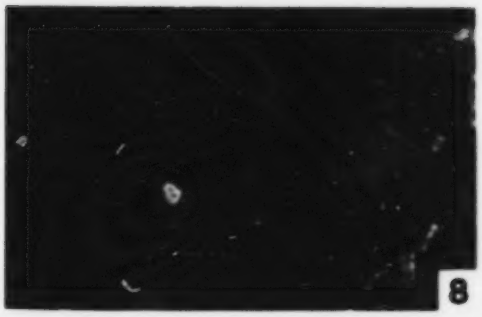
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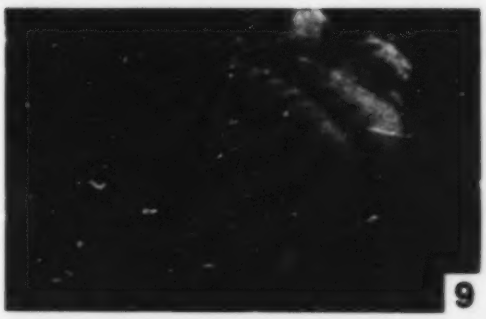
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Plate 3

Isoteloides peri Fortey, 1979a

Barbace Cove Member of the Boat Harbour Formation.

Figure 1 Cranidium: dorsal view, NFM F-99, x 6, BH-94

Figure 2 Hypostoma: dorsal view, NFM F-118, x 7, BH-94

Figure 3 Hypostoma: dorsal view, GSC 86001, x 4, unknown stratigraphic level within Bed 39 of Section BHS-6 of Boat Harbour composite section

Figure 4 Librigena: dorsal view, NFM F-103, x 4, BH-94

Figure 5 Librigena: dorsal view, GSC 86002, x 5, BH-94

Figure 6 Pygidium: dorsal view, NFM F-102, x 5, BH-94

Figures 7, 8 Pygidium: dorsal and lateral views, GSC 86003, x 7, BH-94

PLATE 3

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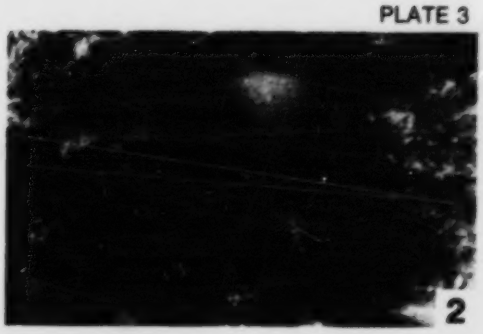
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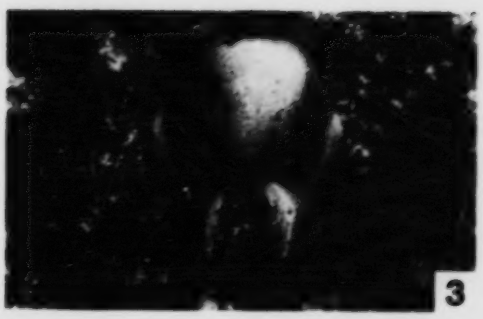
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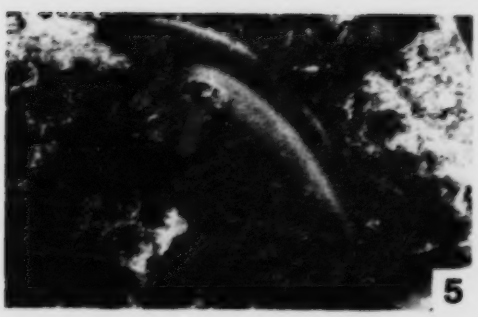
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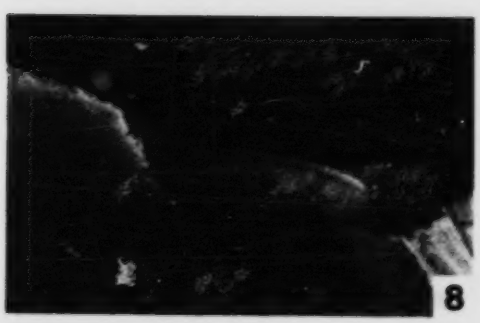
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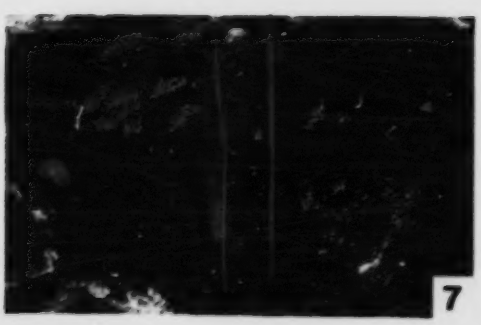
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Plate 4

Hillyardina minuspustulata sp. nov.

Lower member of the Boat Harbour Formation, Boat Harbour, BH-9.

Figures 1 to 3 **HOLOTYPE,** cranidium: dorsal, lateral and anterior views, NFM F-127, x 7

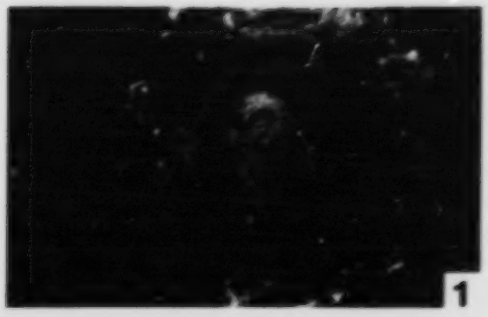
Figures 4 to 6 **Paratype,** cranidium: dorsal, lateral and anterior views, NFM F-128, x 7

Figure 7 Cranidium: dorsal view, GSC 86004, x 8

Figure 8 Cranidium: dorsal view, GSC 86005, x 8

Figure 9 Cranidium: dorsal view, GSC 86006, x 8

PLATE 4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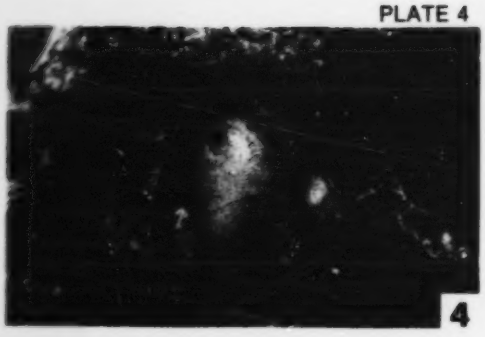
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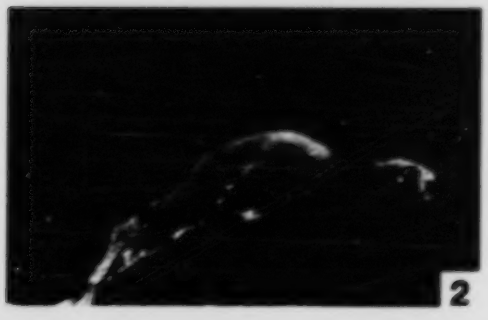
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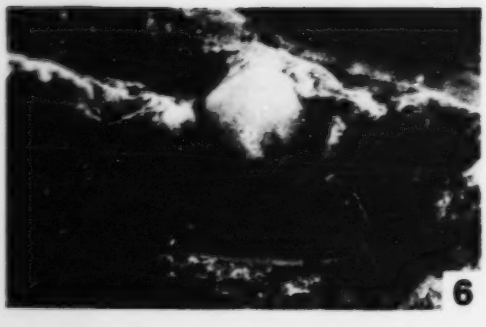
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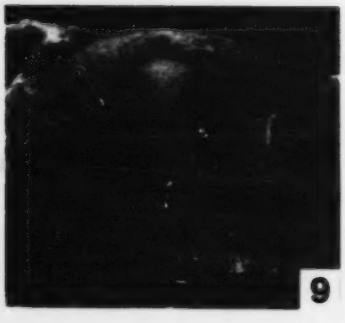
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Plate 5

Hillyardina minuspustulata sp. nov.

Lower member of the Boat Harbour Formation, Boat Harbour, BH-9.

Figure 1 **Paratype,** librigena: dorsal view, NFM F-129, x 8

Figures 2, 3 Librigena: dorsal and lateral views, GSC 86007, x 8

Figures 4, 5 Librigena: dorsal and lateral views, GSC 86008, x 8

Figures 6 to 9 **Paratype,** pygidium: dorsal, lateral, posterior and oblique posterior views, NFM F-130, x 8

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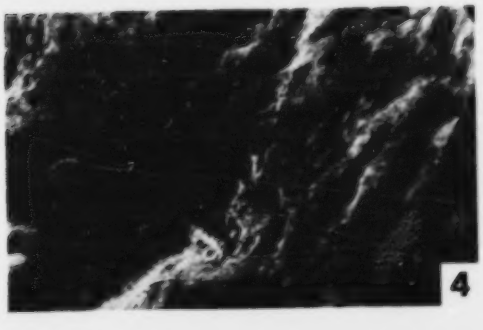
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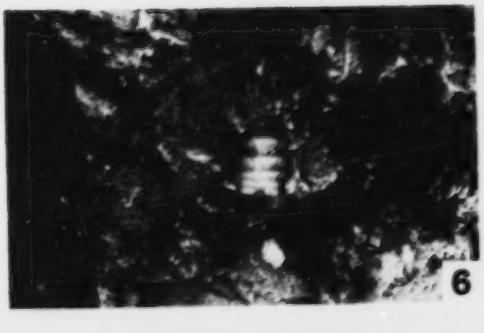
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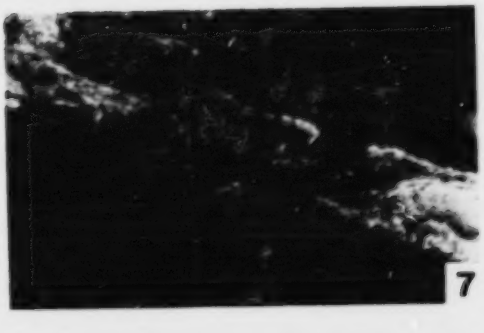
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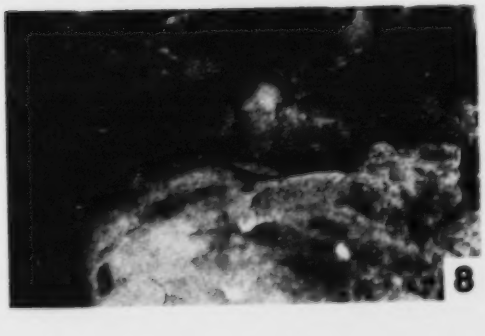
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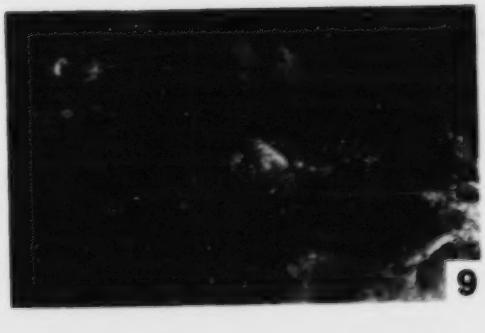
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Plate 6

Hillyardina levis sp. nov.

Lower member of the Boat Harbour Formation.

Figures 1 to 3 **Paratype,** cranidium: dorsal, lateral and anterior views, NFM F-93, x 6, Boat Harbour, BH-18

Figure 4 **Paratype,** cranidium: dorsal view, NFM F-133, x 4, Boat Harbour, BH-18

Figure 5 **HOLOTYPE,** cranidium: dorsal view, NFM F-90, x 5, Boat Harbour, BH-18

Figure 6 **Paratype,** dorsal shield (incomplete–latex cast of external mould): dorsal view, NFM F-131, x 4, Old Ferrolle Island, Brig Bay area

Figures 7, 8 **Paratype,** librigena, (latex cast of external mould): dorsal and lateral views, NFM F-92, x 6, Boat Harbour, BH-18

Figures 9, 10 **Paratype,** librigena: dorsal and lateral views, NFM F-132, x 6, Boat Harbour, BH-18

PLATE 6

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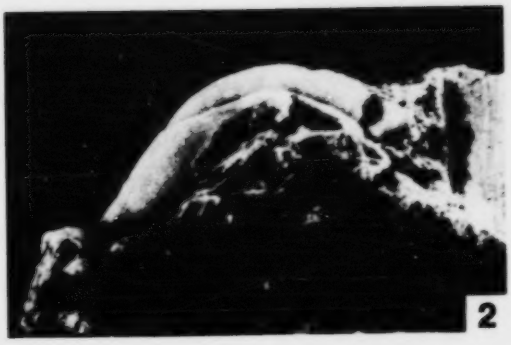
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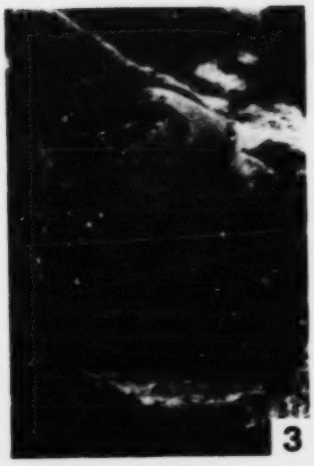
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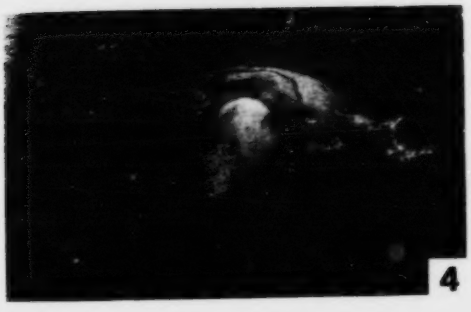
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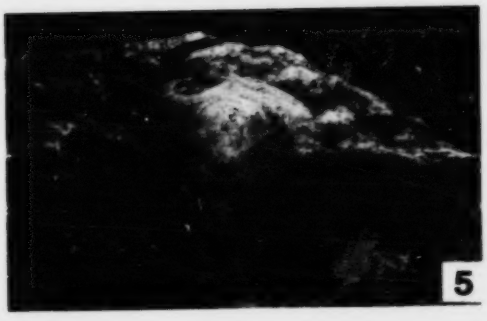
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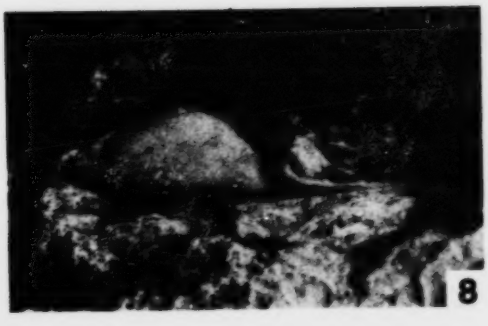
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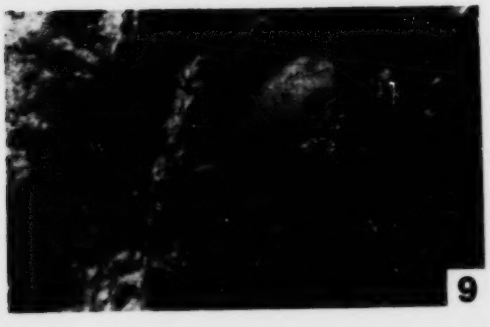
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Plate 7

Hillyardina levis sp. nov.

Lower member of the Boat Harbour Formation, Boat Harbour.

Figures 1, 2 Librigena: dorsal and lateral views, GSC 86009, x 8, BH-23

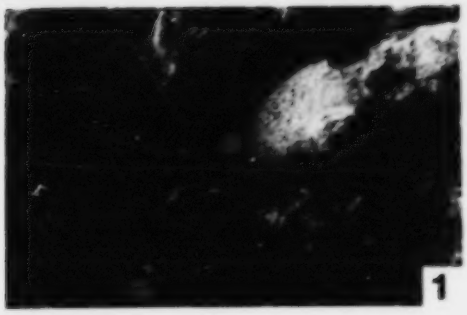
Figure 3 Librigena: dorsal view, GSC 86010, x 5, BH-18

Figure 4 Librigena: dorsal view, GSC 86011, x 5, BH-18

Figure 5 Librigena: dorsal view, GSC 86012, x 7, BH-18

Figure 6 **Paratype,** pygidium, (latex cast of external mould): dorsal view, NFM F-91, x 8, BH-18

Figures 7 to 10 **Paratype,** pygidium: dorsal, lateral, posterior and oblique posterior views, NFM F-134, x 8, BH-30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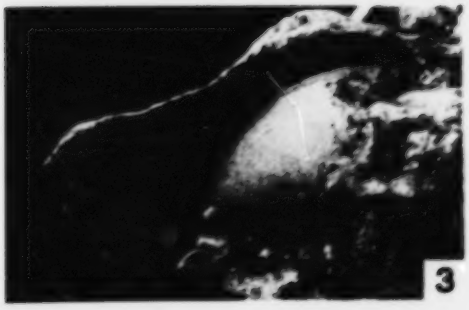
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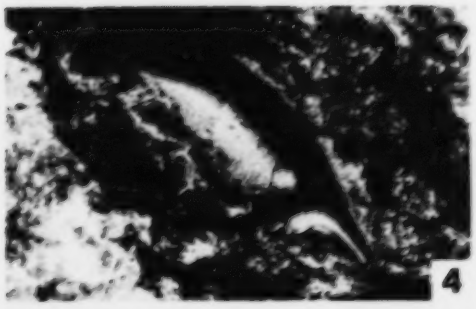
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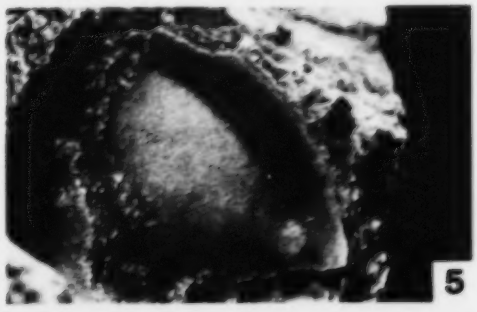
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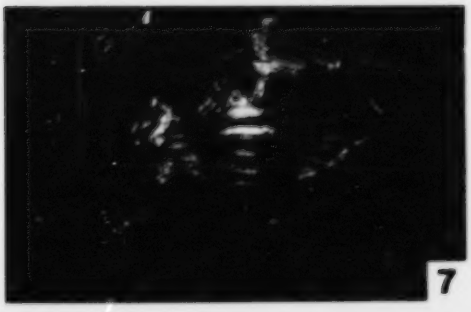
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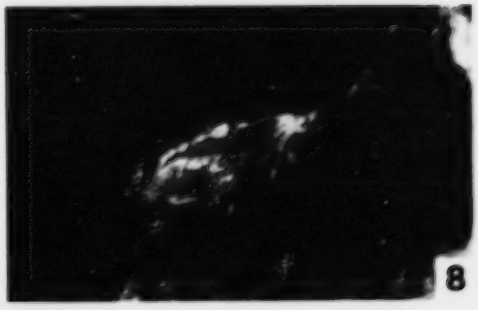
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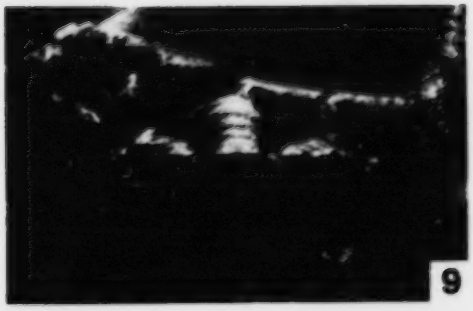
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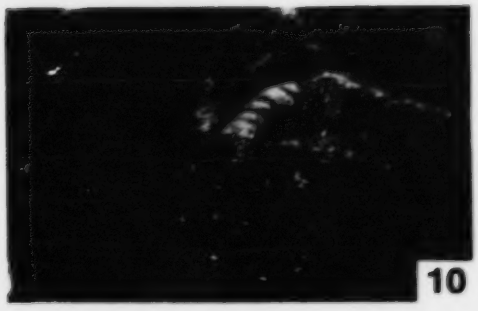
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Plate 8

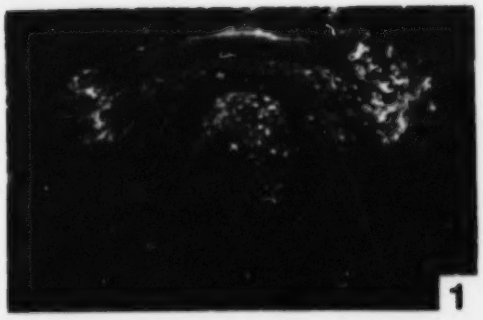
Hystricurus oculilunatus Ross, 1951

Garden City Formation, northeastern Utah, U.S.A.

Figures 1 to 4 Cranidium: dorsal, lateral, anterior and oblique anterior views, YPM 18299 (the original of Ross, 1951; Plate 10, figures 8,9,12), x 4

Lower member of the Boat Harbour Formation, Boat Harbour, BH-28.

Figures 5 to 8 Cranidium, (latex cast of external mould): dorsal, lateral, anterior and oblique anterior views, NFM F-135, x 2.5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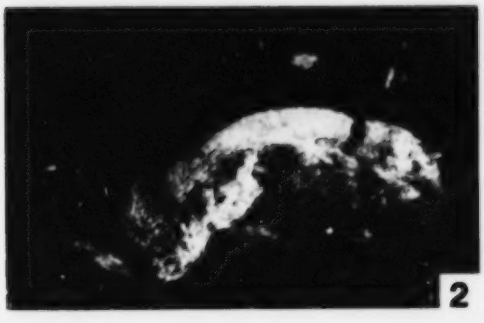
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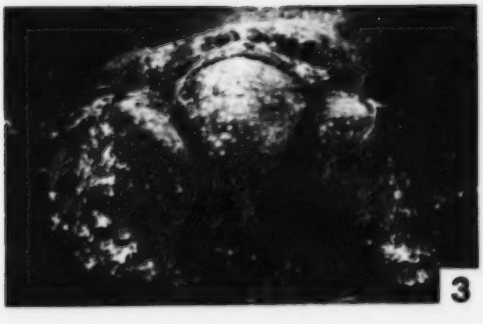
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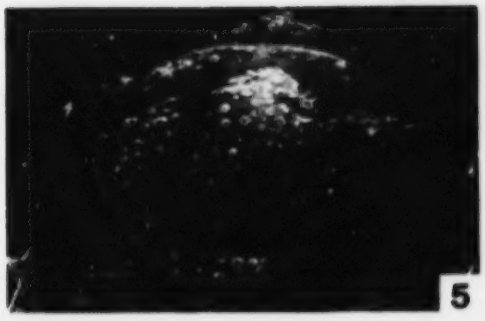
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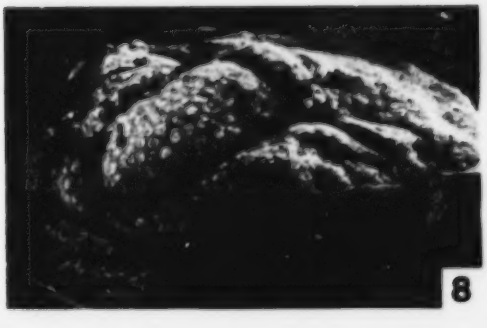
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Plate 9

Hystricurus oculilunatus Ross, 1951

Fort Ann (= Lower Bascom) Formation, Plattsburgh, New York, U.S.A.

Figures 1, 2 Cranidium: dorsal and anterior views, AMNH 41335 (the original of Whitfield, 1889a; Plate 13, figures 15,16), x 2.5

Figures 3 to 6 Cranidium: dorsal, anterior, oblique anterior and lateral views, AMNH 41336 (the original of Whitfield, 1889a; Plate 13, figure 17), x 3

Lower member of the Boat Harbour Formation, Boat Harbour, BH-28.

Figures 7 to 10 Cranidium, dorsal, anterior, oblique anterior and lateral views, NFM F-80, x 4

PLATE 9

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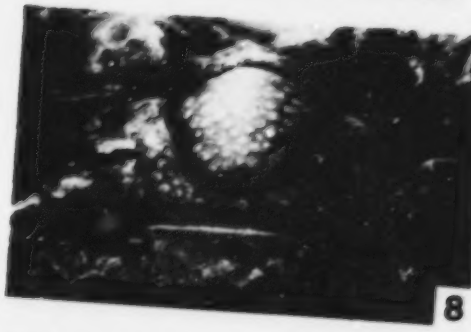
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Plate 10

Hystricurus oculilunatus Ross, 1951

Lower member of the Boat Harbour Formation.

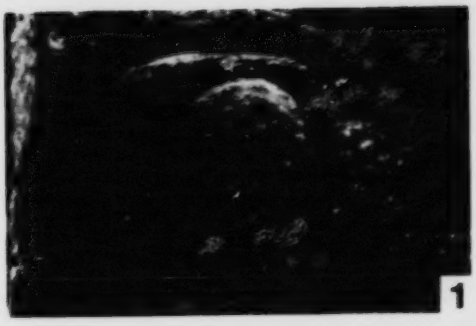
Figures 1, 2 Cranidium: dorsal and lateral views, GSC 86013, x 2.5, Beach Point, Dog Peninsula, Brig Bay area

Figures 3, 4 Librigena: dorsal and lateral views, NFM F-137, x 2.5, Boat Harbour, BH-18

Figures 5, 6 Librigena: dorsal and lateral views, GSC 86014, x 5 and x 4, respectively, Beach Point, Dog Peninsula, Brig Bay area

Figures 7 to 10 Pygidium: dorsal, lateral, posterior and oblique posterior views, NFM F-136, x 2.5, Boat Harbour, BH-16

PLATE 10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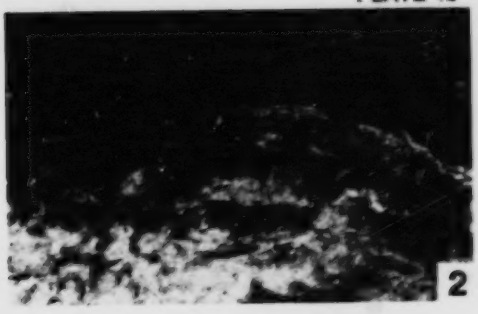
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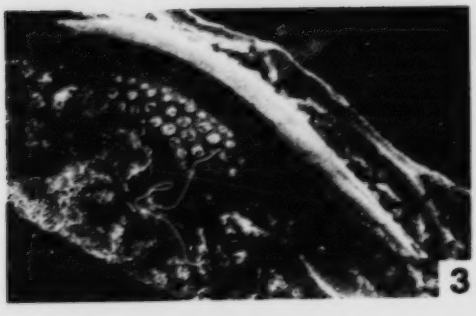
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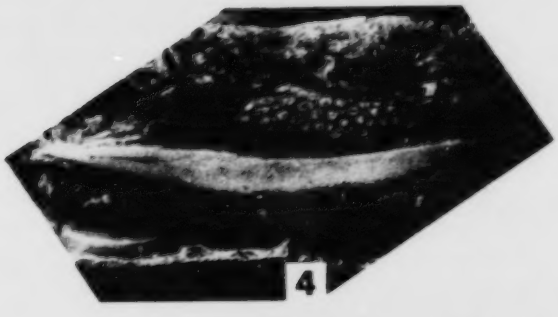
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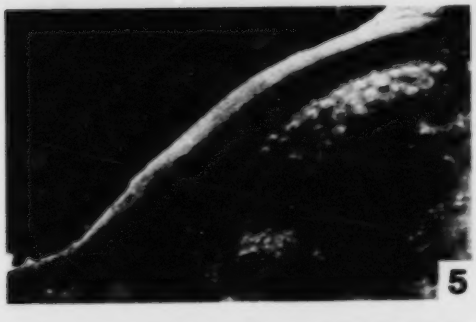
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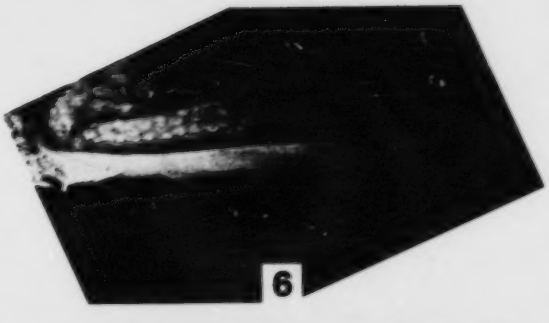
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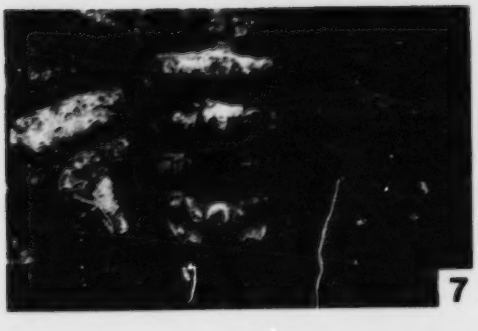
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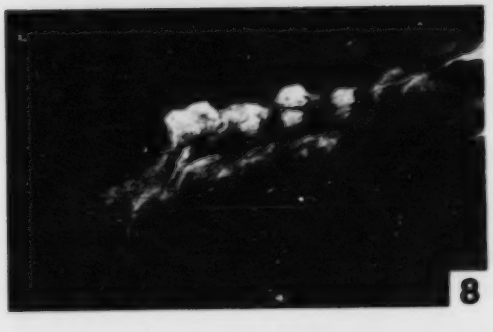
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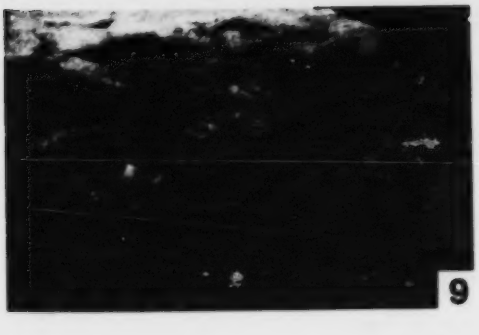
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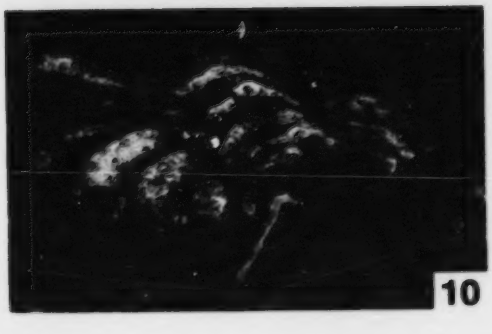
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Plate 11

Hystricurus oculilunatus Ross, 1951

Lower member of the Boat Harbour Formation.

Figure 1 Pygidium: dorsal view, GSC 86015, x 3, BH-28

Figure 2 Pygidium: dorsal view, NFM F-138, x 4, Beach Point, Dog Peninsula, Brig Bay area

Figures 3 to 6 Pygidium: dorsal, lateral, posterior and oblique posterior views, NFM F-81, x 5, Beach Point, Dog Peninsula, Brig Bay area

Figures 12, 13 Pygidium: dorsal and posterior views, GSC 86016, x 4, Boat Harbour, BH-28

Fort Ann (= Lower Bascom) Formation, Plattsburgh, New York, U.S.A.

Figures 7 to 11 Pygidium: dorsal, lateral, posterior, oblique right and left posterior views, AMNH 41339 (the original of Whitfield, 1889a; Plate 13, figures 20, 21), x 5

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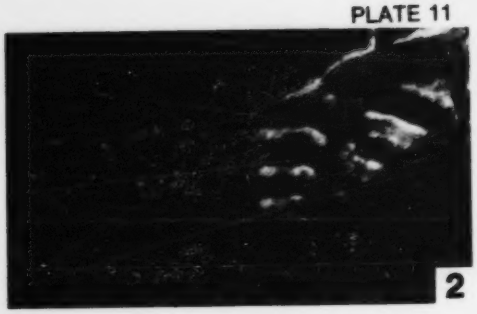
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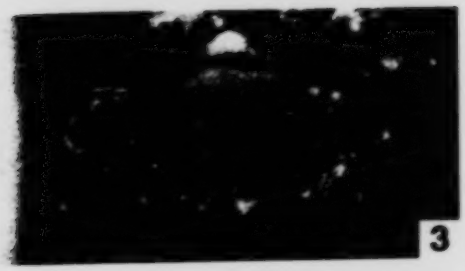
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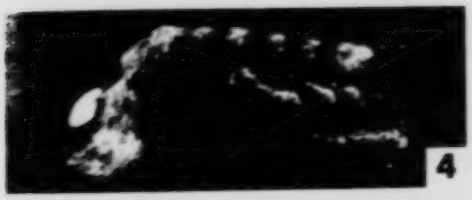
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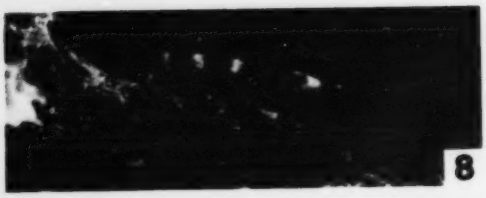
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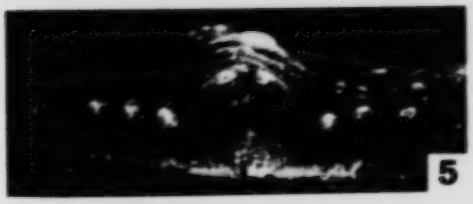
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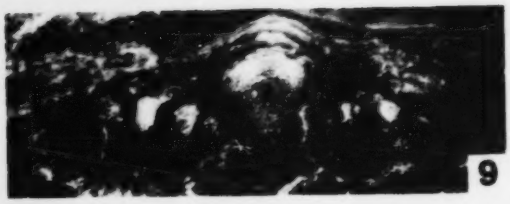
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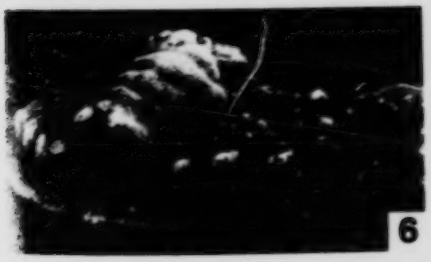
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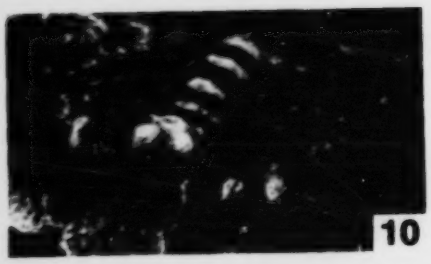
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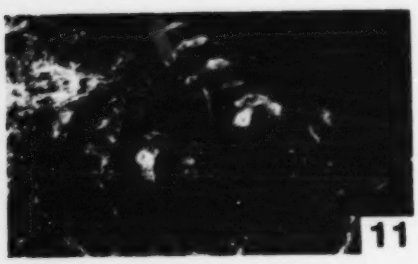
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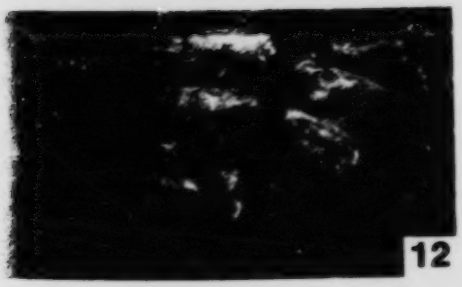
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13

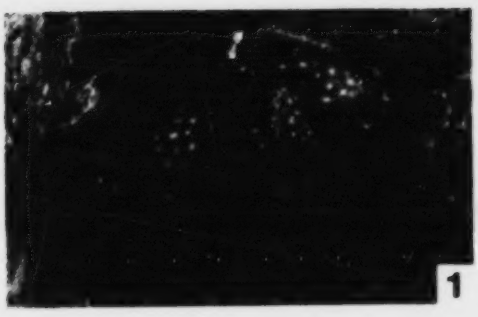
Plate 12

Hystricurus deflectus Heller, 1954

Lower member of the Boat Harbour Formation, Boat Harbour.

Figures 1 to 3	Cranidium: dorsal, anterior and oblique anterior views, NFM F-82, x 8, BH-18
Figures 4 to 7	Cranidium: dorsal, anterior, oblique anterior and lateral views, NFM F-140, x 4
Figure 8	Librigena: dorsal view, GSC 86017, x 7, BH-24
Figures 9, 10	Librigena: dorsal and lateral views, NFM F-139, x 8, BH-18

PLATE 12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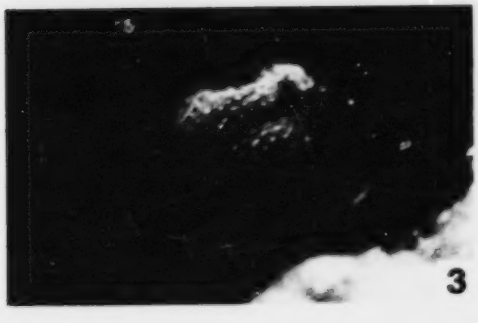
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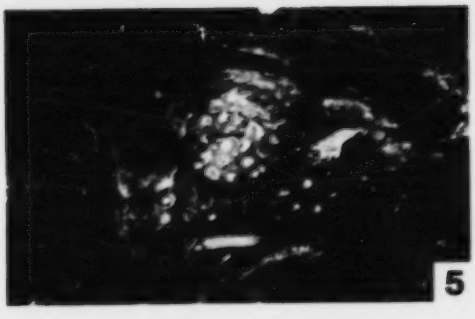
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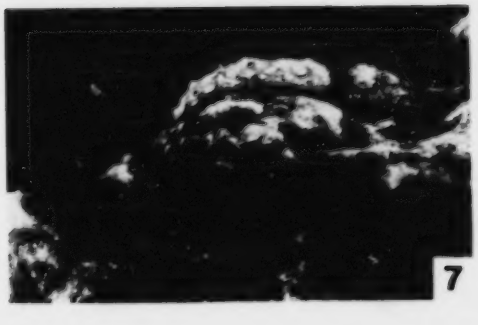
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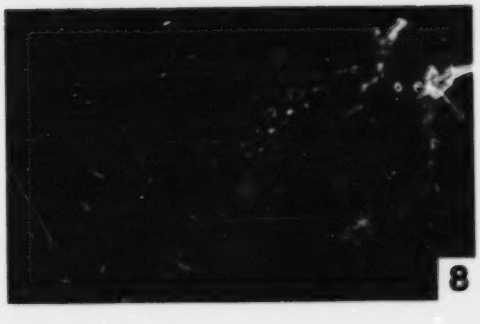
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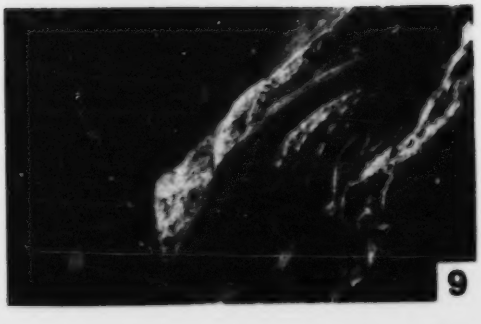
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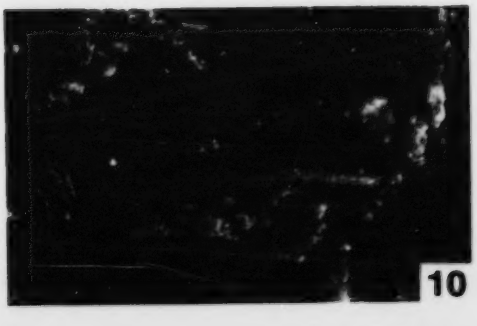
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Plate 13

Hystricurus deflectus Heller, 1954

Lower member of the Boat Harbour Formation, Boat Harbour.

Figures 1, 2 Librigena, (latex cast of external mould): dorsal and lateral views, GSC 86018, x 4, BH-24

Figures 3 to 6 Pygidium: dorsal, posterior, oblique posterior and lateral views, NFM F-83, x 8, BH-18

Figures 7, 8 Pygidium: dorsal and posterior views, GSC 86019, x 4, BH-18

Figures 9, 10 Pygidium: dorsal and posterior views, GSC 86046, x 6, BH-18

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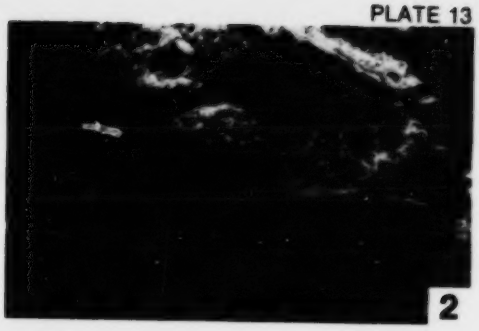
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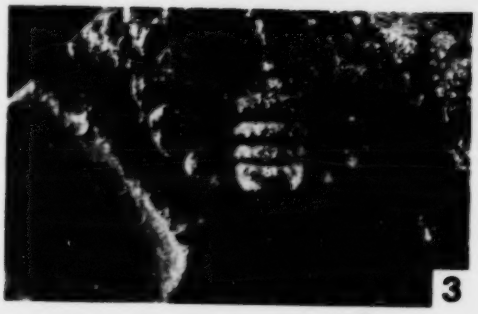
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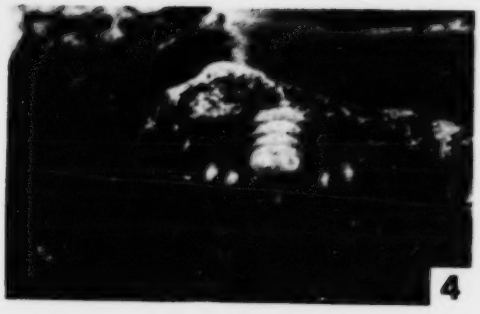
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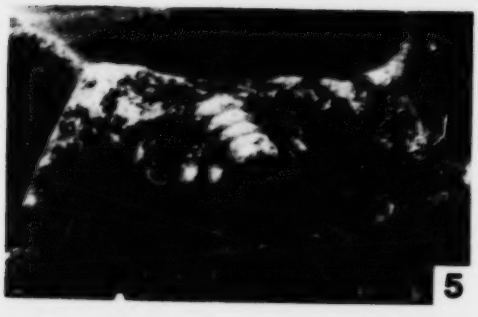
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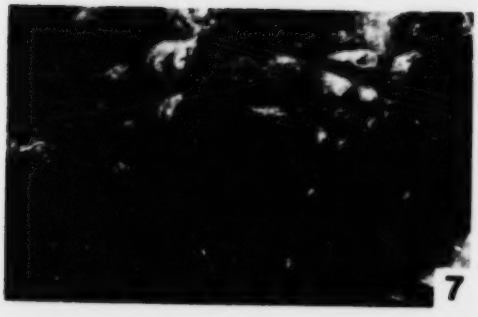
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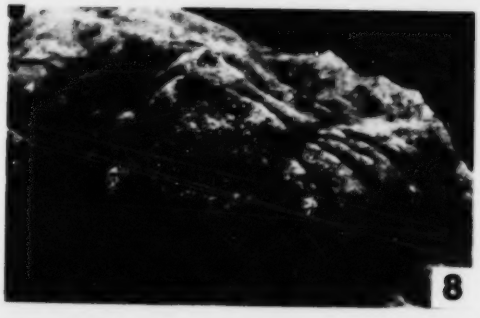
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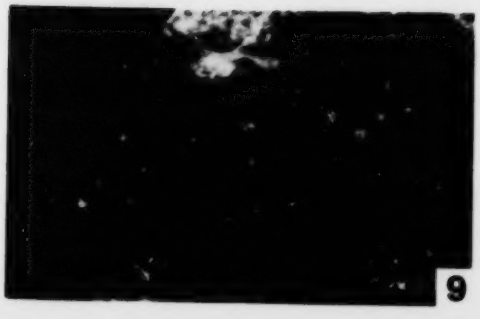
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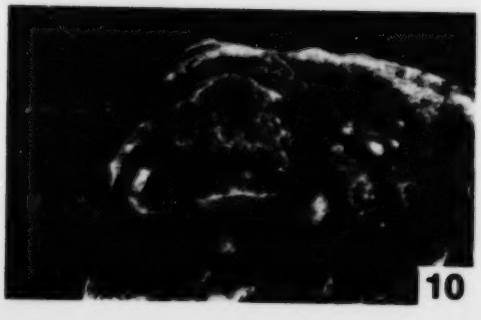
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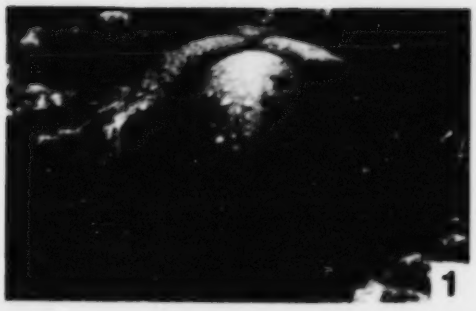
Plate 14

Parahystricurus smithiae sp. nov.

Lower member of the Boat Harbour Formation, Boat Harbour, BH-30.

Figures 1 to 4 **HOLOTYPE,** cranidium: dorsal, anterior, oblique anterior and lateral views, NFM F-88, x 7

Figures 5 to 8 **Paratype,** cranidium: dorsal, anterior, oblique anterior and lateral views, NFM F-142, x 8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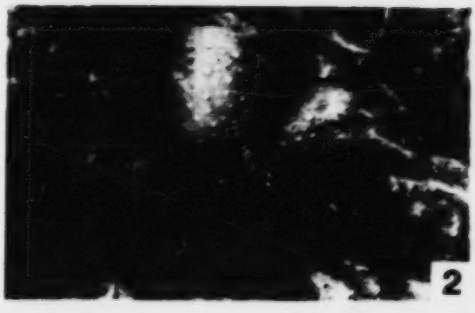
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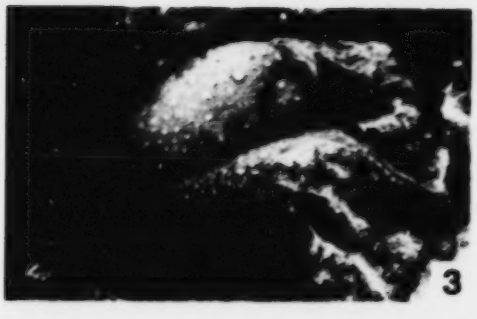
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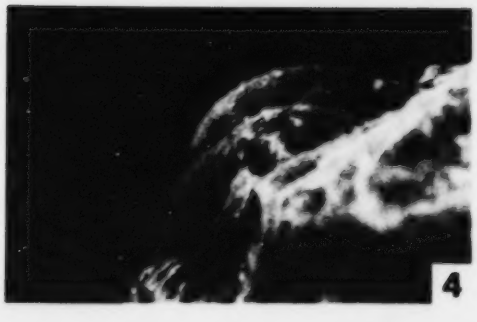
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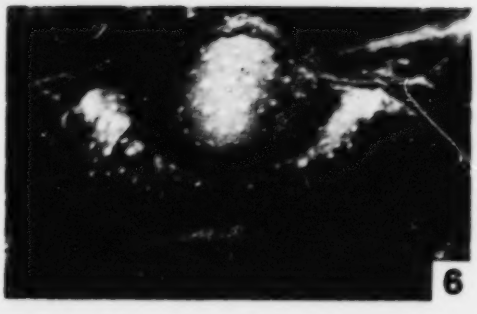
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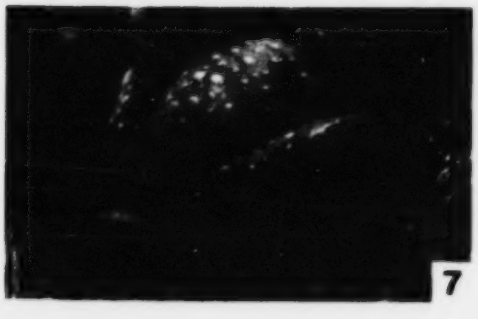
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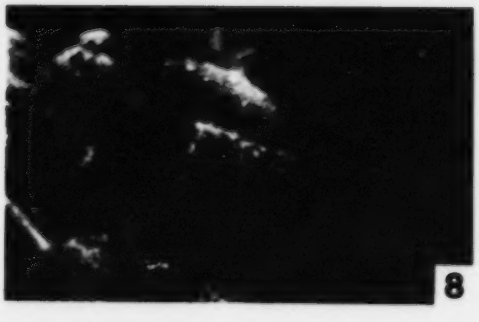
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Plate 15

Parahystricurus smithiae sp. nov.

Lower member of the Boat Harbour Formation, Boat Harbour.

Figure 1 Cranidium: dorsal view, GSC 86020, x 8, BH-18

Figure 2 Cranidium: dorsal view, GSC 86021, x 8, BH-18

Figure 3 Cranidium: dorsal view, GSC 86022, x 8, BH-18

Figure 4 Cranidium: dorsal view, GSC 86023, x 8, BH-18

Figures 5, 6 **Paratype,** librigena: dorsal and lateral views, NFM F-143, x 8, BH-18

Figures 7, 8 **Paratype,** librigena, (latex cast of internal mould): dorsal and lateral views, NFM F-144, x 8, BH-30

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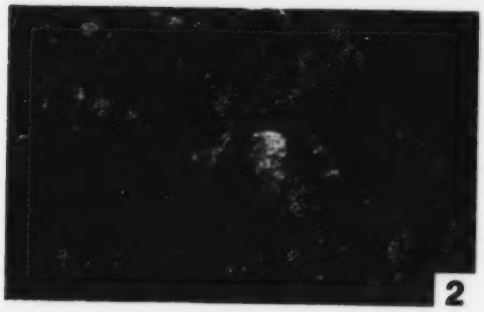
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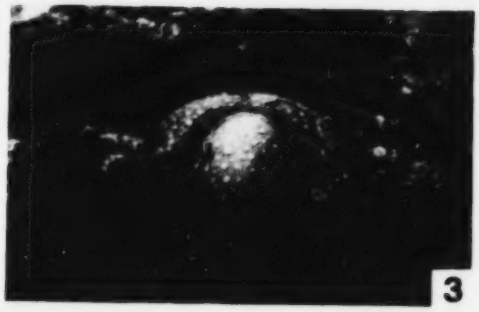
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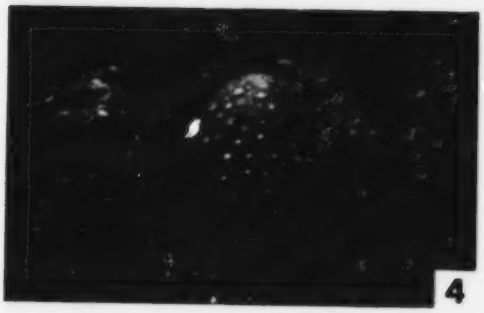
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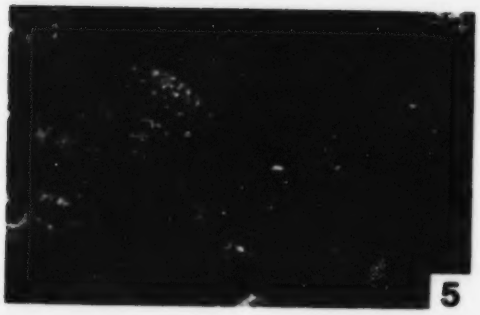
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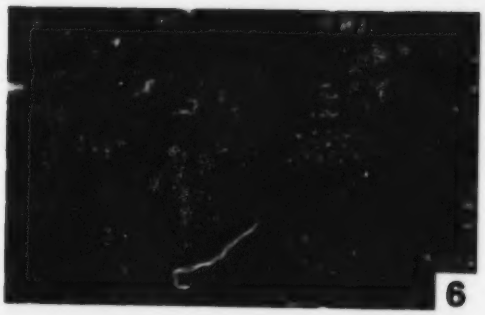
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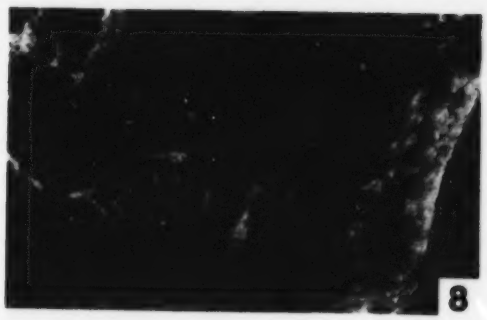
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Plate 16

Parahystricurus smithiae sp. nov.

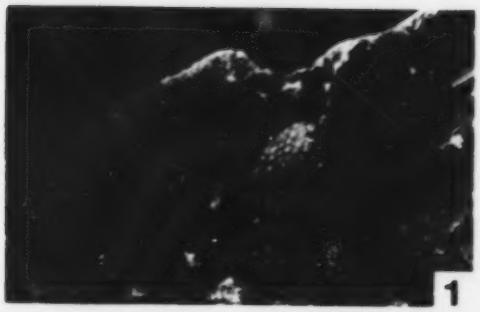
Lower member of the Boat Harbour Formation, Boat Harbour.

Figures 1, 2 Librigena: dorsal and lateral views, GSC 86024, x 8, BH-18

Figures 3, 4 Librigena: dorsal and lateral views, GSC 86025, x 8, BH-18

Figures 5, 6 Librigena: dorsal and lateral views, GSC 86026, x 8, BH-18

Figures 7 to 10 **Paratype,** pygidium: dorsal, posterior, oblique posterior and lateral views, NFM F-89, x 8, BH-30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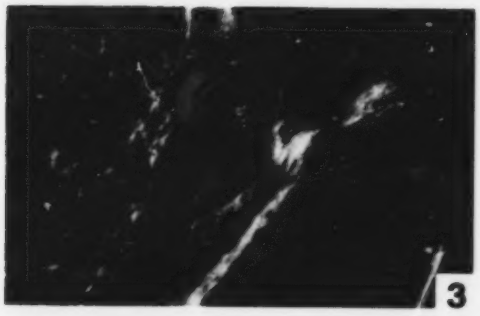
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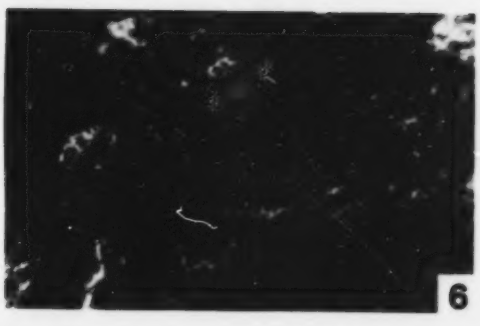
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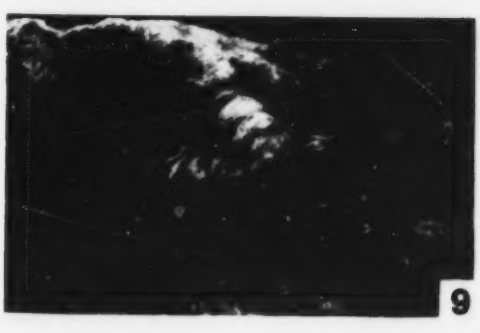
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Plate 17

Paraplethopeltis cordai (Billings, 1859)

Levis Formation, Levis, Quebec.

Figures 1 to 4 **Syntype,** cranidium: dorsal, anterior, oblique anterior and lateral views, GSC 836c, x 4

Paraplethopeltis seelyi (Whitfield, 1889a)

Lower member of the Boat Harbour Formation.

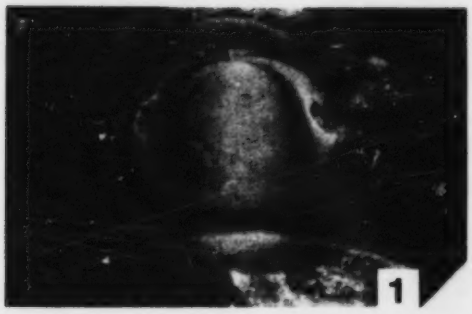
Figure 5 Cranidium: dorsal view, NFM F-106, x 4, Moyrac Island, Brig Bay area

Figure 6 Cranidium: dorsal view, GSC 86027, x 8, Boat Harbour, BH-24

Figure 7 Cranidium, (latex cast of external mould): dorsal view, NFM F-145, x 4, Eddies Cove West, Unit 9 of Pratt's (1979) section

Fort Ann (= Lower Bascom) Formation, Plattsburgh, New York, U.S.A.

Figure 8 **Lectotype,** cranidium: dorsal view, AMNH 35504 (the original of Whitfield, 1889a; Plate 13, figures 11,12), x 2.5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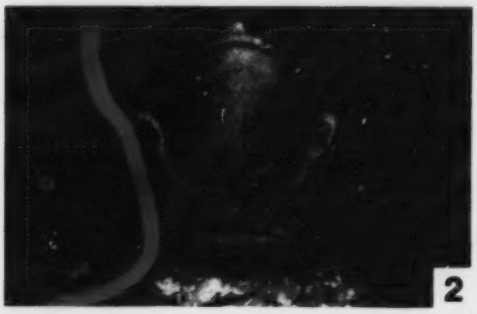
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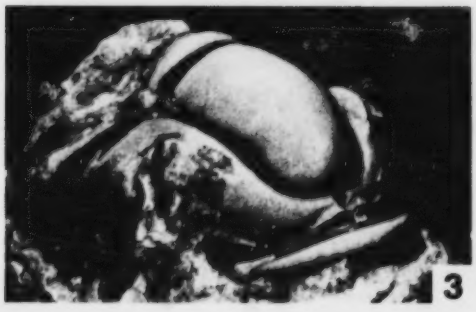
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Plate 18

Paraplethopeltis seelyi (Whitfield, 1889a)

Lower member of the Boat Harbour Formation, Eddies Cove West, Unit 9 of Pratt's (1979) section.

Figures 1 to 3 Cranidium, (latex cast of external mould): anterior, lateral and oblique anterior views, NFM F-145, x 4

Fort Ann (= Lower Bascom) Formation, Plattsburgh, New York, U.S.A.

Figures 4 to 6 **Lectotype,** cranidium: anterior, lateral and oblique anterior views, AMNH 35504 (the original of Whitfield, 1889a; Plate 13, figures 11,12), x 2.5

Lower member of the Boat Harbour Formation, Eddies Cove West, Unit 9 of Pratt's (1979) section.

Figures 7, 8 Cranidium: dorsal and anterior views, NFM F-105, x 2.5

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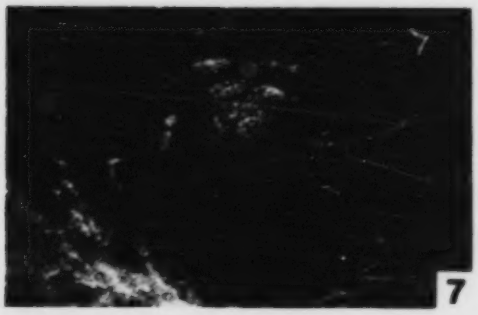
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Plate 19

Paraplethopeltis seelyi (Whitfield, 1889a)

Lower member of the Boat Harbour Formation.

Figures 1, 2 Librigena, (latex cast of external mould): dorsal and lateral views, NFM F-146, x 8, Moyrac Island, Brig Bay area

Figures 3, 4 Pygidium: dorsal and posterior views, NFM F-107, x 1.5, Boat Harbour, BH-24.

Fort Ann (= Lower Bascom) Formation, Plattsburg, New York, U.S.A.

Figures 5, 6 **Plesiotype,** librigena: dorsal and lateral views, AMNH 35503 (the original of Whitfield, 1889a; Plate 13, figure 10), x 3

Figures 7, 8 **Plesiotype,** pygidium: dorsal and posterior views, AMNH 35505 (the original of Whitfield, 1889a; Plate 13, figures 13,14), x 5

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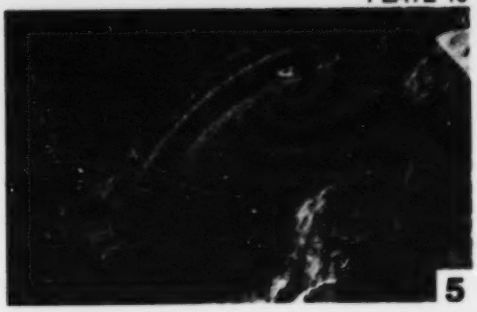
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Plate 20

Paraplethopeltis seelyi (Whitfield, 1889a)

Lower member of the Boat Harbour Formation, Boat Harbour, BH-24

Figures 1, 2 Pygidium: lateral and right oblique posterior views, NFM F-107, x 1.5

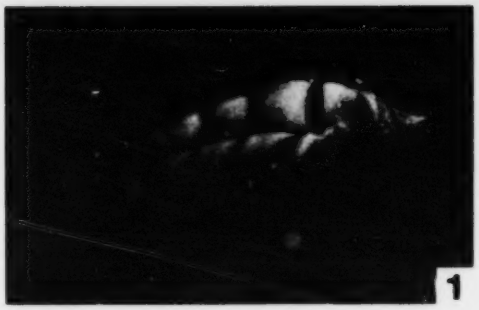
Fort Ann (= Lower Bascom) Formation, Plattsburgh, New York, U.S.A.

Figures 3 to 5 **Plesiotype,** pygidium: lateral and right and left oblique posterior views, AMNH 35505 (the original of Whitfield, 1889a; Plate 13, figures 13,14), x 5

Gen. nov. A sp. nov. A

Lower member of the Boat Harbour Formation, Boat Harbour, BH-38.

Figures 6 to 9 Cranidium: dorsal, anterior, oblique anterior and lateral views, NFM F-141, x 8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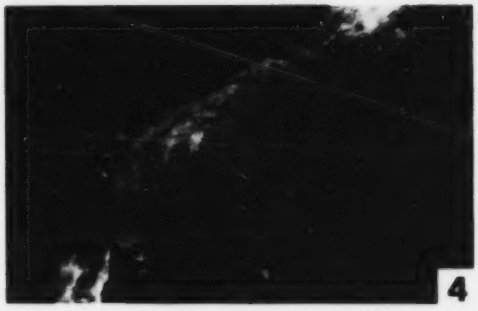
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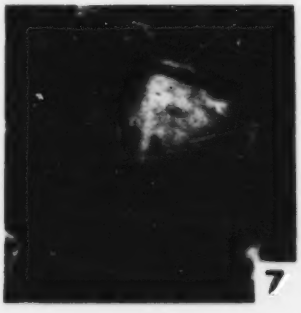
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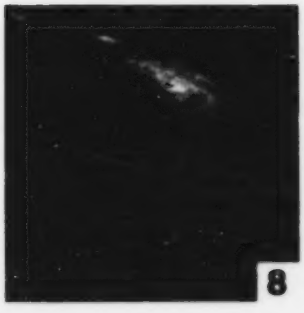
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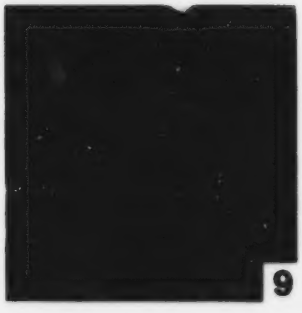
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Plate 21

Jeffersonia mediacrista Cullison, 1944

Rich Fountain Formation, Missouri–northern Arkansas, U.S.A.

Figures 1 to 4 **HOLOTYPE,** cranidium, (modelling-clay cast of external mould): dorsal, anterior, oblique anterior and lateral views, USNM 15593 (the original of Cullison, 1944; Plate XXXIV, figures 25, 26), x 6

Gen. nov. B sp. nov. A

Lower member of the Boat Harbour Formation, Boat Harbour, BH-34.

Figures 5 to 8 Cranidium, (latex cast of external mould): dorsal, anterior, oblique anterior and lateral views, NFM F-154, x 8

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Plate 22

Bolbocephalus convexus (Billings, 1865)

Figures 1 to 4 Cranidium: dorsal, anterior, lateral and oblique anterior views, NFM F-108, x 4, Barbace Cove Member of the Boat Harbour Formation, Boat Harbour, BH-46

Figures 5 to 8 Pygidium: dorsal, posterior, lateral and oblique posterior views, NFM F-147, x 6, lower limestone sequence of the Catoche Formation, Boat Harbour, BH-101–BH-110

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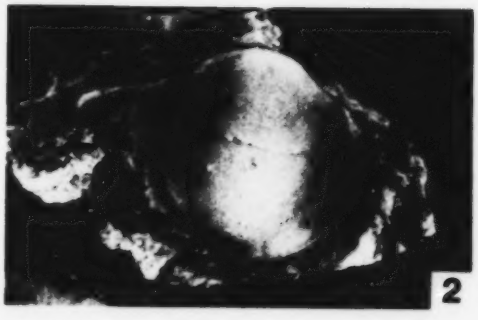
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Plate 23

Bolbocephalus stevensi sp. nov.

Barbace Cove Member of the Boat Harbour Formation, Boat Harbour.

Figures 1 to 4 **Paratype,** cranidium: dorsal, anterior, lateral and oblique anterior views, NFM F-148, x 5, BH-69

Figures 5 to 8 **HOLOTYPE,** pygidium: dorsal, posterior, lateral and oblique posterior views, NFM F-149, x 6, BH-95

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Plate 24

Bolbocephalus stevensi sp. nov.

Barbace Cove Member of the Boat Harbour Formation, Boat Harbour.

Figures 1 to 3 **Paratype,** pygidium, (internal mould): dorsal, posterior and lateral views, NFM F-151, x 8, BH-87

Figures 4, 5 **Paratype,** pygidium, (latex cast of external mould): dorsal and lateral views, NFM F-150, x 3, BH-59

Figures 6 to 9 Pygidium: dorsal, posterior, lateral, left oblique and right posterior views, GSC 86028, x 3, BH-51

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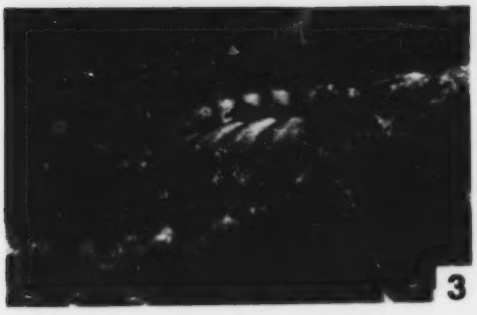
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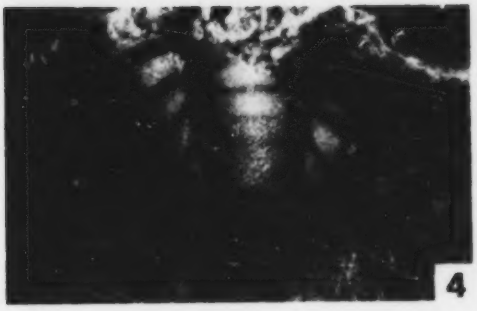
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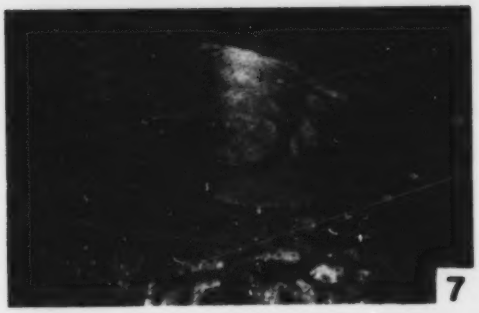
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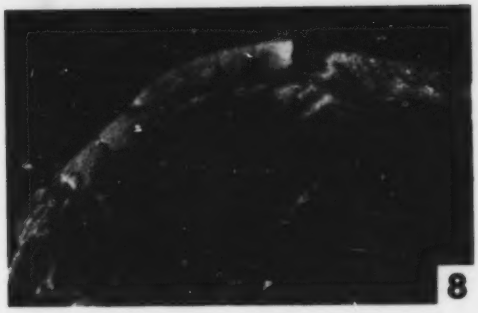
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Plate 25

Bolbocephalus kindlei sp. nov.

Cape Weber Formation, Ella Island, east-central Greenland.

Figures 1 to 4 **Paratype,** pygidium: dorsal, posterior, lateral and oblique posterior views, MMH 3714 (the original of Poulsen, 1937; Plate 8, figure 2), x 6

Catoche Formation, Burnt Island.

Figures 5 to 8 **Paratype,** pygidium: dorsal, posterior, lateral and oblique posterior views, GSC 82296, x 2.5

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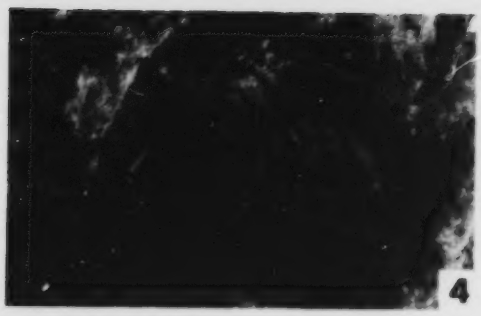
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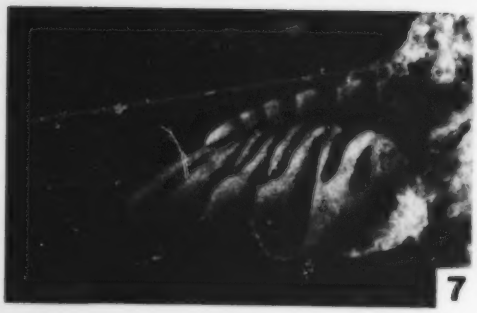
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Plate 26

Bolbocephalus kindlei sp. nov.

Lower limestone sequence of the Catoche Formation, Cape Norman.

Figures 1 to 4 **HOLOTYPE,** pygidium: dorsal, posterior, lateral and oblique posterior views, NFM F-209, x 4

Catochia ornata Fortey, 1979a

Lower limestone sequence of the Catoche Formation, Boat Harbour, BH-101–BH-110.

Figures 5, 6 Librigena: dorsal and lateral views, NFM F-264, x 6

Jeffersonia angustimarginata sp. nov.

Barbace Cove Member of the Boat Harbour Formation, Boat Harbour, BH-40.

Figures 7, 8 **Paratype,** cranidium: dorsal and lateral views, NFM F-152, x 3

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Plate 27

Jeffersonia angustimarginata sp. nov.

Figures 1, 2 **Paratype,** cranidium: anterior and lateral views, NFM F-153, x 2.5, lower limestone sequence of the Catoche Formation, Boat Harbour, BH-112

Figures 3, 4 Cranidium: dorsal and lateral views, GSC 86029, x 2.5, Barbace Cove Member of the Boat Harbour Formation, Boat Harbour, BH-49

Figures 5, 6 **Paratype,** librigena: dorsal and lateral views, NFM F-265, x 6, Barbace Cove Member of the Boat Harbour Formation, Boat Harbour, BH-49

Figures 7 to 10 **HOLOTYPE,** pygidium: dorsal, lateral, posterior and oblique posterior views, NFM F-87, x 6, lower limestone sequence of the Catoche Formation, Boat Harbour, BH-101

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Plate 28

Jeffersonia angustimarginata sp. nov.

Lower limestone sequence of the Catoche Formation, Boat Harbour, BH-101.

Figure 1 **HOLOTYPE,** pygidium: inclined posterior view, NFM F-87, x 6

Figures 2, 3 Pygidium: dorsal and lateral views, GSC 86030, x 3

Peltabellia knighti sp. nov.

Barbace Cove Member of the Boat Harbour Formation, Boat Harbour.

Figure 4 **HOLOTYPE,** pygidium: dorsal view, NFM F-157, x 8, BH-46

Figure 5 **Paratype,** cranidium: dorsal view, NFM F-156, x 5, BH-47

Figure 6 **Paratype,** cranidium: dorsal view, NFM F-112, x 4, BH-46

Figure 7 **Paratype,** librigena: dorsal view, NFM F-113, x 3, BH-46

Figure 8 Librigena: dorsal view, GSC 86031, x 4, BH-46

Figure 9 **Paratype,** pygidium: dorsal view, NFM F-114, x 5, BH-46

Figure 10 Pygidium: dorsal view, GSC 86032, x 5, BH-45

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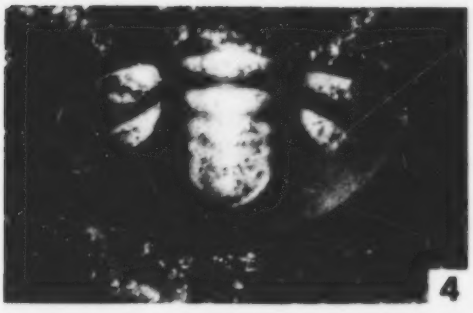
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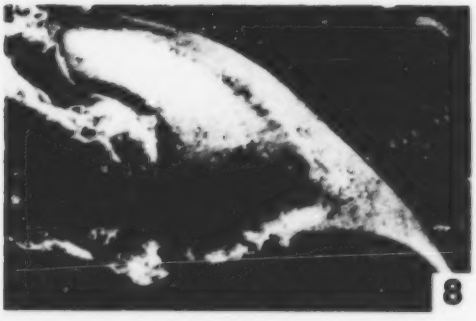
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Plate 29

Peltabellia knighti sp. nov.

Barbace Cove Member of the Boat Harbour Formation, Boat Harbour, BH-46.

Figure 1 Pygidium: dorsal view, GSC 86033, x 4

Figure 2 Pygidium: dorsal view, GSC 86034, x 5

Peltabellia sp. cf. *P. peltabella* (Ross, 1951)

Barbace Cove Member of the Boat Harbour Formation, Boat Harbour, BH-49.

Figures 3 to 5 Pygidium: (latex cast of internal mould), dorsal, posterior and lateral views, NFM F-159, x 2.5

Petigurus nero (Billings, 1865)

Barbace Cove Member of the Boat Harbour Formation, Boat Harbour, BH-49.

Figure 6 Pygidium: dorsal view, NFM F-85, x 5

Petigurus sp. nov. A.

Catoche Formation, Barbace Point, Port au Choix Peninsula.

Figure 7 Pygidium: dorsal view, NFM F-300, x 4

Strigigenalis brevicaudata sp. nov.

Barbace Cove Member of the Boat Harbour Formation, Boat Harbour.

Figure 8 **Paratype,** cranidium: dorsal view, NFM F-160, x 6, unknown stratigraphic interval within Bed 39 of Section BHS-6

Figure 9 **Paratype,** librigena: dorsal view, NFM F-161, x 8, unknown stratigraphic level within Bed 39 of Section BHS-6

Figure 10 **Paratype,** pygidium: dorsal view, NFM F-115, x 6, BH-92

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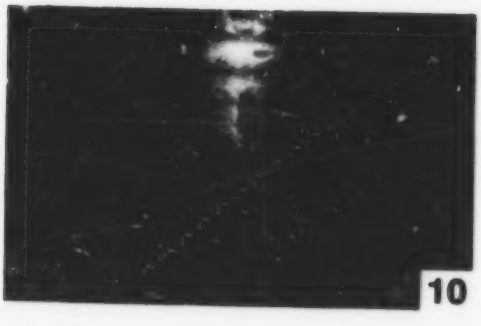
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Plate 30

Strigigenalis brevicaudata sp. nov.

Barbace Cove Member of the Boat Harbour Formation, Boat Harbour.

Figures 1 to 3 **HOLOTYPE,** pygidium: dorsal, posterior and lateral views, NFM F-163, x 4, BH-67

Figures 4 to 6 Pygidium, (latex cast of internal mould): dorsal, posterior and lateral views, GSC 86035, x 6, BH-59

Figure 7 **Paratype,** pygidium: dorsal view, NFM F-162, x 7, BH-59

Figure 8 Pygidium: dorsal view, GSC 86036, x 6, BH-59

Figure 9 Pygidium: dorsal view, GSC 86037, x 5, BH-59

Figure 10 Pygidium: dorsal view, GSC 86038, x 4, BH-69

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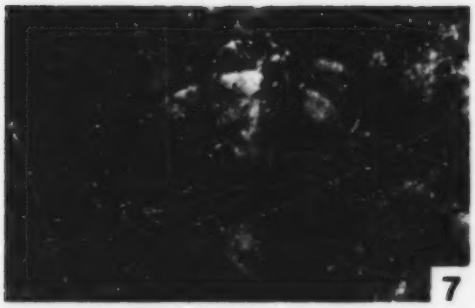
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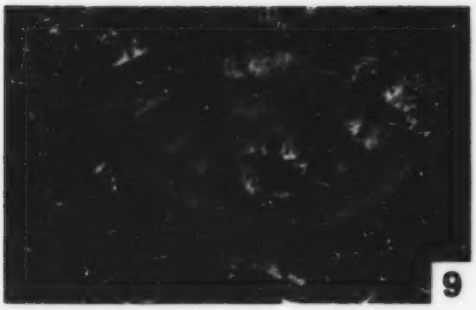
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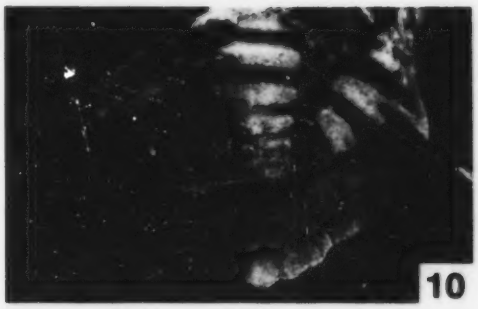
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Plate 31

Strigigenalis caudata (Billings, 1865)

Barbace Cove Member of the Boat Harbour Formation, Boat Harbour, BH-94.

Figures 1 to 4 Pygidium: dorsal, posterior, oblique posterior and lateral views, NFM F-164, NFM F-165, x 3

Cotter Formation, Missouri–northern Arkansas, U.S.A.

Figures 5 to 8 Pygidium: dorsal, posterior, oblique posterior and lateral views, YPM 17407 (formerly 17182–the original of Cullison, 1944; Plate XXXV, figures 25, 26), x 3

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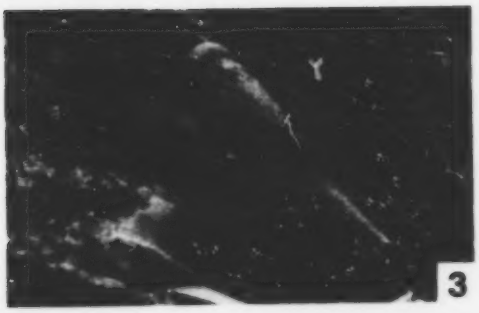
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Plate 32

Benthamaspis hintzei sp. nov.

Lower limestone sequence of the Catoche Formation, Boat Harbour.

Figures 1, 2 **Paratype,** cranidium: dorsal and lateral views, NFM F-173, x 8, BH-101–BH-110

Figure 3 **Paratype,** cranidium: dorsal view, NFM F-174, x 8, BH-112

Figure 4 **HOLOTYPE,** pygidium: dorsal view, NFM F-175, x 6, BH-110

Figure 5 Pygidium: dorsal view, GSC 86039, x 8, BH-110

Barbace Cove Member of the Boat Harbour Formation, BH-62.

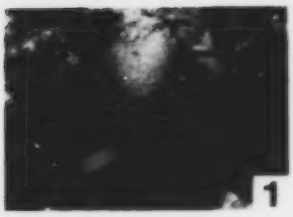
Figures 6 to 8 **Paratype,** pygidium: dorsal, posterior and lateral views, NFM F-176, x 8

Benthamaspis sp. cf. *B. conica* Fortey, 1979a

Lower limestone sequence of the Catoche Formation, Cape Norman, CN-35.

Figures 9 to 11 Pygidium: dorsal, posterior and lateral views, NFM F-266, x 8

PLATE 32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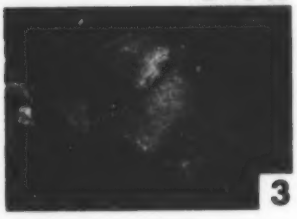
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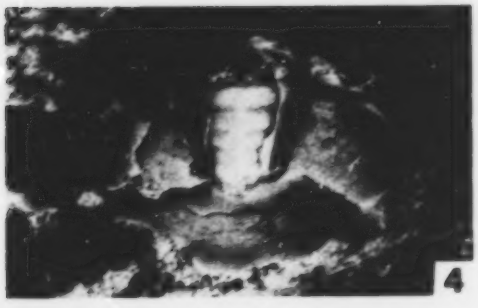
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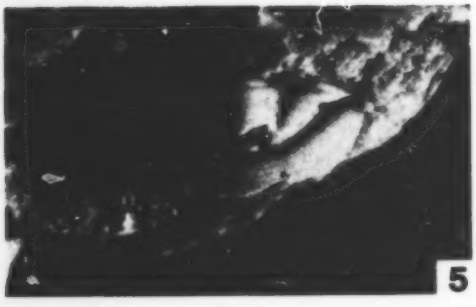
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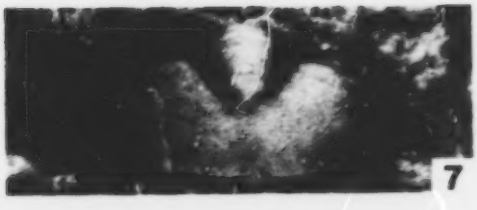
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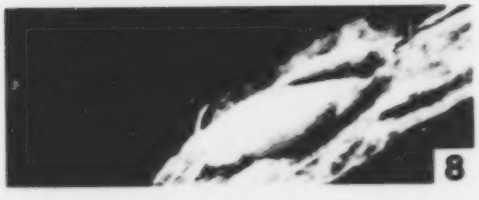
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Plate 33

Grinnellaspis newfoundlandensis sp. nov.

Barbace Cove Member of the Boat Harbour Formation, Boat Harbour.

Figure 1 **Paratype,** cranidium: dorsal view, NFM F-166, x 6, BH-60

Figure 2 **Paratype,** librigena: dorsal view, NFM F-167, x 4, BH-60

Figure 3 **Paratype,** pygidium: dorsal view, NFM F-168, x 5, BH-40

Figure 4 **Paratype,** pygidium: dorsal view, NFM F-169, x 4, BH-49

Figure 5 **HOLOTYPE,** pygidium: dorsal view, NFM F-170, x 4, BH-60

Figure 6 **Paratype,** pygidium, (latex cast of external mould): dorsal view, NFM F-171, x 3, BH-69

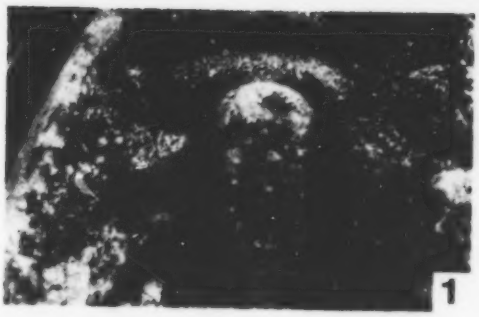
Uromystrum affine (Poulsen, 1937)

Lower limestone sequence of the Catoche Formation, Boat Harbour.

Figure 7 Cranidium: dorsal view, NFM F-95, x 6, BH-101–BH-110

Figure 8 Cranidium: dorsal view, GSC 86040, x 3, BH-114

Figures 9, 10 Librigena: dorsal and lateral views, GSC 86041, x 7, BH-112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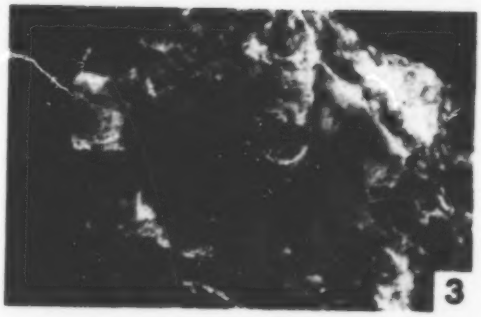
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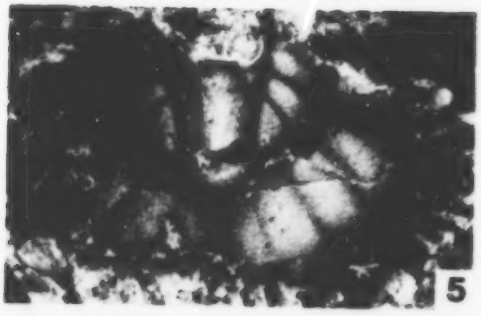
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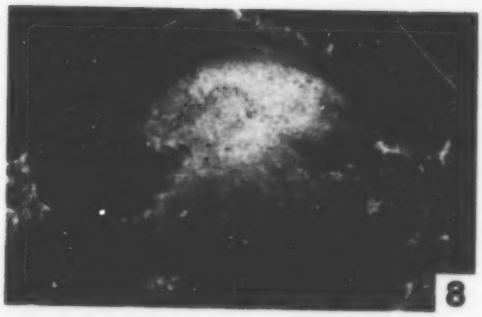
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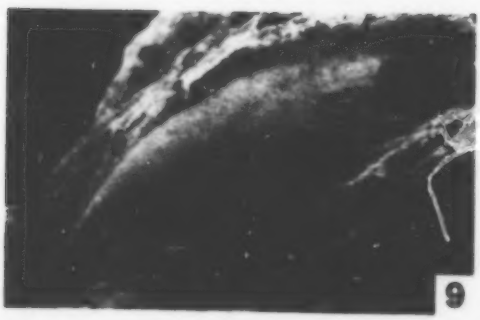
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Plate 34

Uromystrum affine (Poulsen, 1937)

Lower limestone sequence of the Catoche Formation, Boat Harbour.

Figures 1, 2 Librigena: dorsal and lateral views, NFM F-104, x 3, BH-101/BH-110

Figure 3 Pygidium, (latex cast of internal mould): dorsal view, NFM F-96, x 3, BH-103

Cape Weber Formation, Ella Island, east-central Greenland.

Figure 4 **HOLOTYPE,** pygidium, (latex cost of plaster mould): dorsal view, MMH 3705 (the original of Poulsen, 1937; Plate 7, figure 7), x 6

Uromystrum sp. cf. *U. affine* (Poulsen, 1937)

Lower limestone sequence of the Catoche Formation, Cape Norman, CN-34.

Figure 5 Pygidium: dorsal view, NFM F-172, x 3

Ischyrotoma anataphra Fortey, 1979

Lower limestone sequence of the Catoche Formation, Cape Norman, CN-25.

Figure 6 Cephalon: dorsal view, NFM F-177, x 6

Ischyrotoma parallela sp. nov.

Lower limestone sequence of the Catoche Formation, Boat Harbour, BH-101–BH-110.

Figures 7, 8 **HOLOTYPE,** cephalon: dorsal and lateral views, NFM F-178, x 8

PLATE 34

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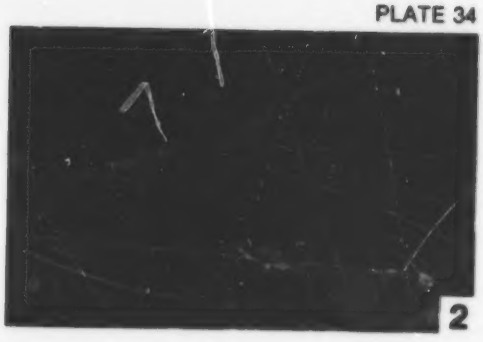
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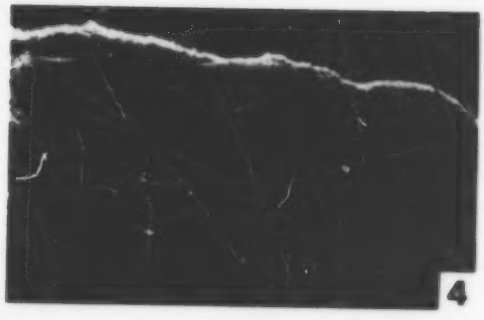
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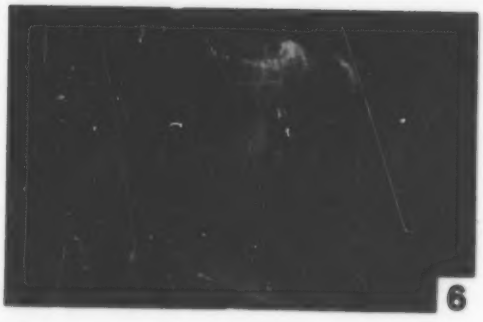
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Plate 35

Ischyrotoma parallela sp. nov.

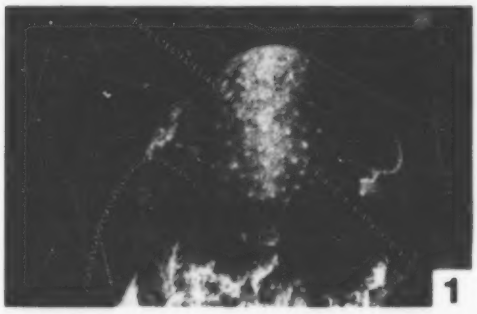
Lower limestone sequence of the Catoche Formation, Boat Harbour.

Figures 1 to 3 **Paratype,** cephalon: dorsal, anterior and lateral views, NFM F-86, x 6, BH-100

Figures 4 to 6 Cephalon: dorsal, anterior and lateral views, GSC 86042, x 8, BH-101–BH-110

Figures 7, 8 **Paratype,** cephalon: anterior and lateral views, NFM F-179, x 8, BH-112

Figures 9, 10 Cranidium: dorsal and lateral views, GSC 86043, x 6, BH-101–BH-110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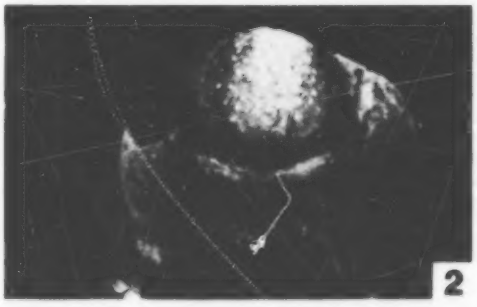
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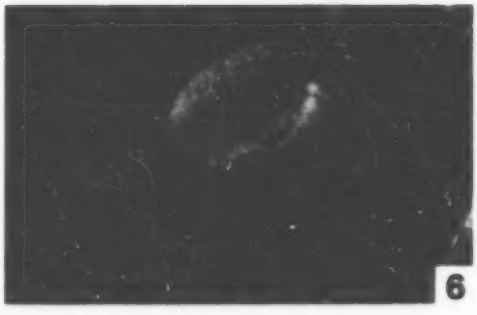
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Plate 36

Randaynia saundersi gen. et sp. nov.

Lower member of the Boat Harbour Formation.

Figures 1 to 3 **Paratype,** cranidium: dorsal, anterior and oblique anterior views, NFM F-119, x 5, Boat Harbour, BH-18

Figure 4 **HOLOTYPE,** dorsal shield: (incomplete, flattened), dorsal view, NFM F-94, x 3, Old Ferrolle Island, Brig Bay area

Figures 5 to 8 **Paratype,** cranidium: dorsal, anterior, oblique anterior and lateral views, NFM F-267, x 8

Figures 9, 10 **Paratype,** librigena: dorsal and lateral views, NFM F-117, x 3, BH-30

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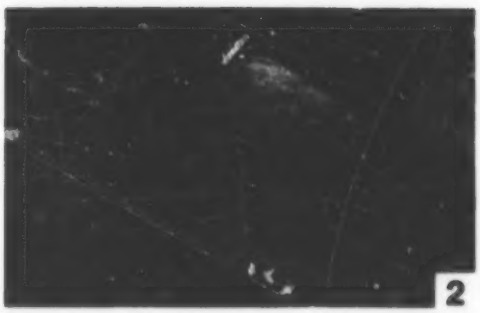
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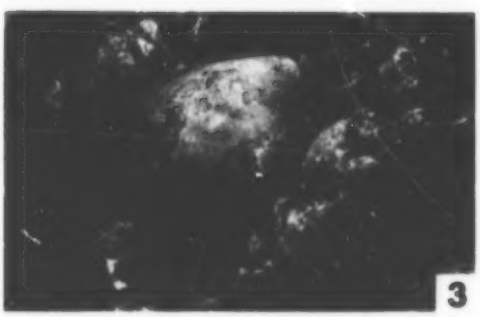
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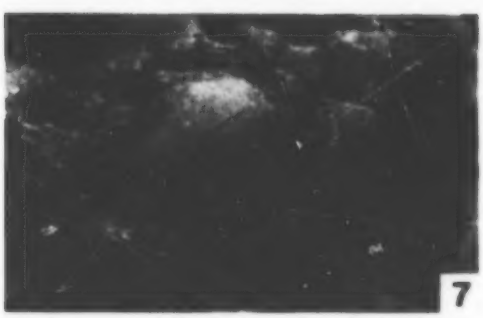
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Plate 37

Randaynia saundersi gen. et sp. nov.

Lower Member of the Boat Harbour Formation, Boat Harbour.

Figure 1 **Paratype,** pygidium, (latex cast of external mould): dorsal view, NFM F-120, x 3, BH-23

Figures 2 to 4 **Paratype,** pygidium: dorsal, posterior and oblique posterior views, NFM F-121, x 6, BH-9

Figure 5 Pygidium: dorsal view, GSC 86044, x 4, BH-23

Figure 6 Pygidium: dorsal view, GSC 86045, x 4, BH-23

Figures 7 to 10 **Paratype,** pygidium: dorsal, posterior, oblique posterior and lateral views, NFM F-122, x 4, BH-30

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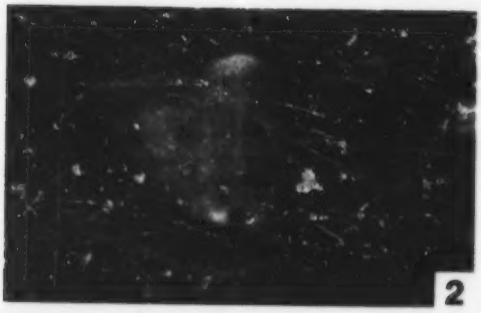
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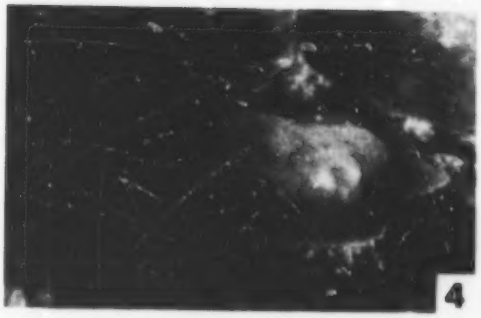
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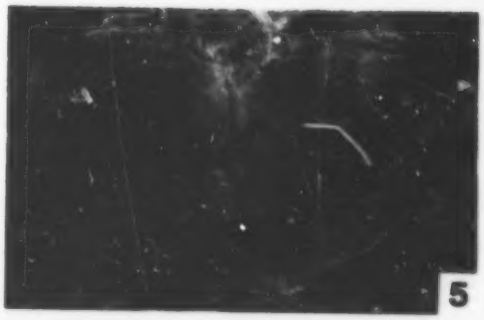
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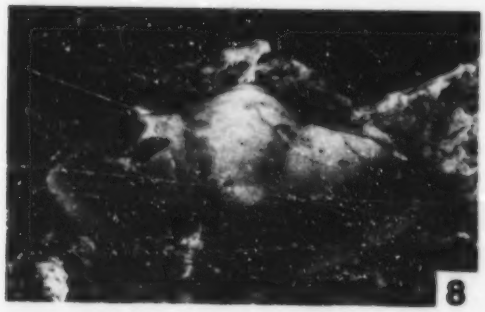
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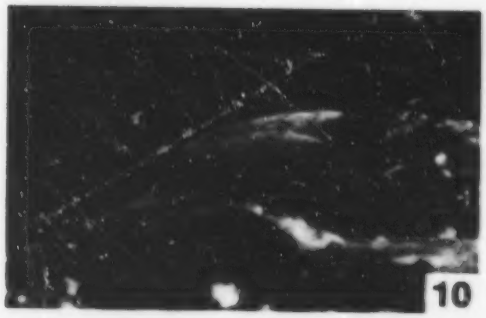
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Plate 38

Randaynia langdoni sp. nov.

Barbace Cove Member of the Boat Harbour Formation, Boat Harbour, BH-47.

Figures 1 to 4 **Paratype,** cranidium: dorsal, anterior, oblique anterior and lateral views, NFM F-123, x 8

Figures 5, 6 **Paratype,** librigena, (latex cast of external mould): dorsal and lateral views, NFM F-124, x 7

Figure 7 **Paratype,** transitory pygidium retaining one thoracic segment, dorsal view, NFM F-126, x 8

Figures 8 to 11 **HOLOTYPE,** pygidium: dorsal, posterior, oblique posterior and lateral views, NFM F-125, x 6

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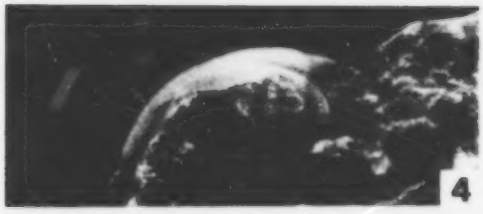
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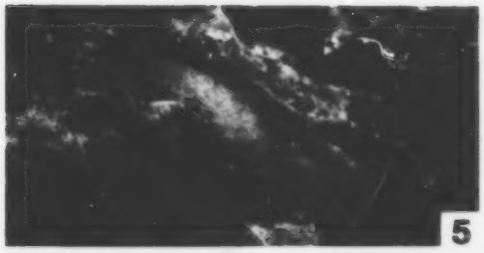
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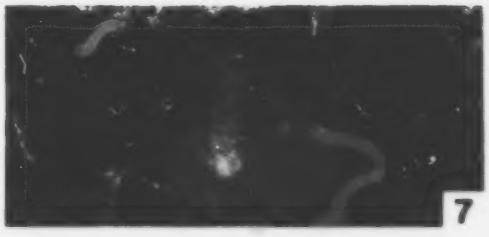
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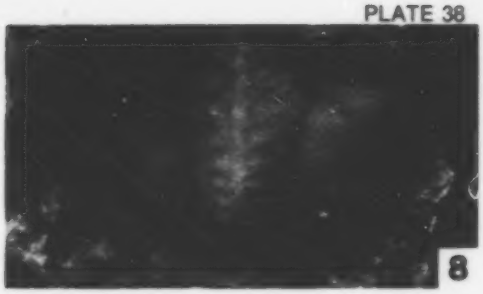
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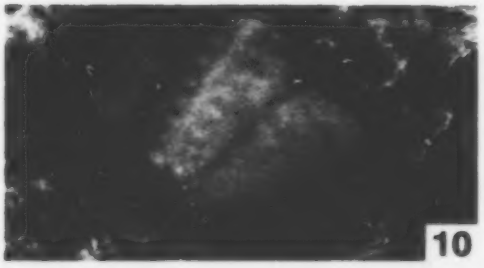
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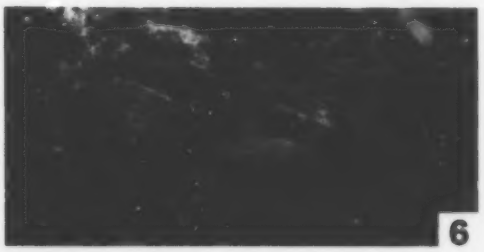
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